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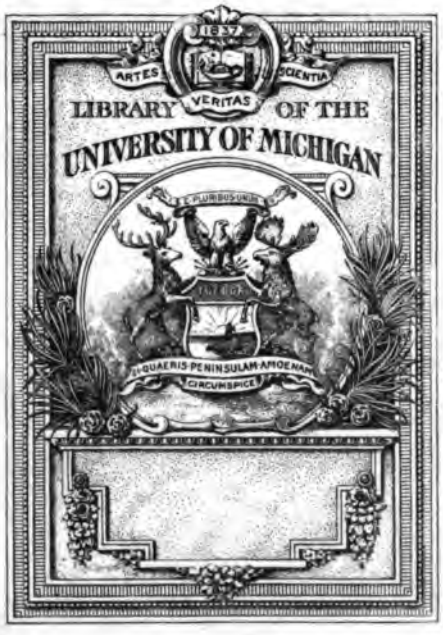
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TRANSACTIONS

OF THE

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

EDITED BY THE SECRETARY OF THE INSTITUTION.

VOLUME X.

TENTH SESSION, 1893-94.

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SOUTH WALES INSTITUTE OF ENGINEERS, *Vol.* XVIII., *No.* 4.—Sussman's Electric Safety-lamp. The Hydrogen Oil Safety-lamp. Test Chamber for Gas-testing Apparatus. Progress made in Coking during the last few years. Alterations to Pumping Plant at Foxes Bridge Colliery.

SOCIETY OF ENGINEERS, 1892.—Electrical Traction and its Financial Aspect. The Application of Electricity to Hoisting Machinery. Dry Crushing Machinery. Foreign Sewage Precipitation Works. Vacation Visits. The Cleansing of and Ventilation of Pipe Sewers. The Use of Steel Needles in Draining a Tunnel at King's Cross. The Shortland and Nunhead Railway.

UNITED STATES NAVAL INSTITUTE, *Vol.* XIX., *No.* 3, 1893.—Results of some Special Researches at the Torpedo Station. The Origin and Work of the Division of Marine Meteorology Hydrographic Office. A Look in the Track of an Ocean Storm. The Kruka-Hebler Tubular Projectiles. The Buonaccorsi Automobile Torpedo. *Vol.* XX., *No.* 1.—Prize Essay, 1894. The Johnson Cast Steel Armour Piercing Shot. Battle of La Placella. The Ram in Action and in Accident. Note on the Literature of Explosives. Cleaning the Bottoms of Steel Ships by Divers when

Docking is Impracticable. A Gunshot Injury Produced by the New Projectile of Small Calibre. *No.* 2.—Naval Reform. Consideration on the Battleship in Action. Extreritoriality and Asylum. The Solution for the Elements of the Chronometer. The Children of Nelson. Ship Boats. The Navy and the Nation. Notes on Naval General Courts-martial.

PUBLICATIONS RECEIVED TO DATE, CURRENT NUMBERS OF WHICH LIE ON THE TABLES IN THE READING ROOM :—

Electrical Engineer, 139, Salisbury Court, Fleet Street, London, E.C.
Electrical Review, 22, Paternoster Row, London, E.C.
Engineering, 35 and 36, Bedford Street, Strand, London, W.C.
Engineers' Gazette, Prudential Buildings, Mosley Street, Newcastle-upon-Tyne.
Indian Engineer, 4, Dalhousie Square, Calcutta, British India.
Indian Engineering, Pat. Doyle, Esq., C.E., Star Press, 19, Lall Bazar, Calcutta, British India.
Industries and Iron, 39 and 40, Shoe Lane, London, E.C.
Iron and Coal Trades Review, 342, Strand, London, W.C.
Journal de la Marine le Yacht, 55, Rue de Châteaudun, Paris.
Marine Engineer, 3, Amen Corner, Paternoster Row, London, E.C.
Mechanical World, New Bridge Street, Manchester.
Rivista Marittima, Rome.
Shipping World, Effingham House, Arundel Street, London, E.C.
Stahl und Eisen, Düsseldorf.
The Steamship, 2, Custom House Chambers, Leith.
The Electrician, 1, Salisbury Court, Fleet Street, London, E.C.
The Engineer, 33, Norfolk Street, Strand, London, W.C.
The Engineering Review, 29, Great George Street, London, S.W.
The Practical Engineer, 6, Victoria Station Approach, Manchester.
The Illustrated Official Journal of Patents, Patent Office, London, E.C.
Transport, 35, Parliament Street, London, S.W.

LIST OF OFFICERS.

TENTH SESSION, 1893-94.

President:—ROBERT THOMPSON.

Past-Presidents:

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W. THEO. DOXFORD.
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4, St. Nicholas' Buildings West, Newcastle-upon-Tyne.

COMMITTEES.

TENTH SESSION, 1893-94.

Finance Committee:

WILLIAM BOYD (Chairman).

J. GRAVELL.
A. LAING.
HUGH MACOLL.
W. C. MOUNTAIN.
JAMES PATTERSON.
G. E. MACARTHY (Hon. Treasurer).

Reading Committee:

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M. C. JAMES.
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W. G. SPENCE.
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W. HÖK.
W. C. MOUNTAIN.
JAMES THOMSON, JUN.
R. L. WEIGHTON, M.A.

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A. LAING.
HUGH MACOLL.
J. F. WALLIKER.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Members, July, 1894.

EXPLANATION.

(A.)	Agent and Accountant.	(I. & S. M.)	Iron and Steel Merchants and Manufacturers.
(B. B.)	Boiler Builder.	(M. S.)	Marine Superintendent.
(C. E.)	Civil Engineer.	(N. A.)	Naval Architect.
(E.)	Engineer and Boilermaker.	(R. M.)	Rope Manufacturer.
(E. A.)	Engineering Agent.	(S.)	Shipbuilder.
(E. E.)	Electrical Engineer.	(S. O.)	Ship Owner.
(F. M.)	Forge Master.	(SUR.)	Engineer & Ship Surveyor.

HONORARY MEMBERS.

		ELECTED
The Right Hon. Lord Armstrong, C.B., D.C.L., F.R.S., Cragside, Rothbury		Nov. 1884
The Right Honourable the Earl of Ravensworth, Ravensworth Castle, near Gateshead-on-Tyne...		Nov. 1884
W. H. White, Esq., C.B., LL.D., F.R.S., The Admiralty, Whitehall, London	(N A)	Nov. 1884

MEMBERS.

A.

Abey, Henry, Fairfield, York Road, West Hartlepool	(E)	Jan. 1889
Adamson, Alex., c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness	(S)	Nov. 1885
Adamson, Cumberland, 3, Close Street, Sunderland	(S)	Nov. 1893
Aitchison, Jas., Hylton, Sunderland	(S)	Nov. 1884
Alchin, A. H., Uxbridge Road, London, W.	(E)	Jan. 1885
Alder, Sydney, Edinbro' Buildings, South Shields	(C E & N A)	Nov. 1893
Allan, Jas. McNeal, 3, Parkville, Heaton, Newcastle-on-Tyne ...	(E)	Dec. 1886
Allardes, Wm., c/o Messrs. Harland & Wolff, Ltd., Engine Works, Belfast	(E)	Nov. 1884
Ampuero, Bernardo, Chief of the Chilian Cruiser "Presidenta Pinto," Circulo Naval, Valparaiso	(E)	Mar. 1894
Anderson, Joseph, c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne	(E)	Nov. 1884
Andrew, D., 33, Osborne Road, Jesmond, Newcastle-on-Tyne ...	(SUR)	Jan. 1885
Andrews, Jas., Drawing Office, Messrs. Naval Construction and Armaments Co., Barrow-in-Furness	(E)	Nov. 1884

ELECTED.

Angus, W. J., 9, Ibrox Place, Govan, Glasgow ... ... (E) Oct. 1892
Anthony, Jas., 6, Northumberland Square, North Shields ... ... (S) Oct. 1886
Apolinaris dos Santos, J., Rio Grande-do-Sul, Brazil ... (SUR) Nov. 1891
Archbold, Joseph G., c/o Messrs. Blyth Dry Dock Co., Blyth ... (E) Jan. 1889
Archbold, William, c/o Messrs. E. Scott, Mountain, & Co., The Close, Newcastle-on-Tyne ... ... (E) Mar. 1894
Armstrong, G. S., c/o Mrs. Witcher, South Town, Dartmoor ... (S) Nov. 1884
Armstrong, Joseph, 27, Ripon Street, Sunderland ... ... (S) Nov. 1892
Armstrong, Robert B., 26, Warwick Street, Heaton, Newcastle-on-Tyne ... ... (E) Oct. 1887
Arnison, Geo., Jun., 61, Fawcett Street, Sunderland (N A & SUR) Nov. 1884
Atherton, William Henry, 47, Lovaine Place, Newcastle-on-Tyne (E) Oct. 1891
Atkinson, F. C., 37, Croydon Road, Newcastle-on-Tyne ... ... (E) Dec. 1892
Atkinson, John Joseph, 7, Swiss Road, Elm Park, Fairfield, Liverpool ... ... (E) Mar. 1891
Austin, S. P., Wear Dockyard, Sunderland ... ... (S) Nov. 1884
Austin, W. R., Lloyd's Register of Shipping, Royal Exchange, Middlesbrough ... ... (E SUR) Oct. 1888
Ayre, James Reay, 16, Neptune Road, Wallsend-on-Tyne ... ... (S) Jan. 1894

B.

Bagnall, T. W., The Groves, Winlaton-on-Tyne ... ... (F M) Nov. 1893
Baguley, Ernest Edwin, Lyndhurst, Rowley Park, Stafford ... (E) April 1891
Bailey, James, 3, South Avenue, Ryton-on-Tyne ... ... (E) Nov. 1884
Baines, Geo. Henry, Messrs. Central Marine Engineering Co., West Hartlepool ... ... (E) Oct. 1888
Baird, George, 22, Lovaine Place, North Shields ... ... (E) Oct. 1892
Baird, Robert, 13, Hylton Terrace, North Shields ... ... (E) Jan. 1890
Barclay, James, Lloyd's Register of Shipping, Swansea ... ... (SUR) Nov. 1888
Barley, C. J., c/o Messrs. The Kensington and Knightsbridge Electric Lighting Co., Chapel Place, Brompton Road, London, S.W. ... ... (E) } Graduate, Feb. 1885; Member, Dec. 1886
Barnett, James Rennie, Lilybank House, Johnston, N.B. ... ... (S) Oct. 1889

ELECTED.

Black, J., c/o Messrs. J. Merryweather & Co., West Hartlepool ... (E) Nov. 1888
Black, Wm., Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne (E) Jan. 1885
Blackett, Walter, 60, Marine Parade, Sheerness ... (E) { Graduate, Nov. 1886 / Member, Nov. 1892 }
Blackie, Thomas Reid, Lloyd's Register of Shipping, Dock Office, West Hartlepool ... ... (SUR) Nov. 1890
Blechynden, Alfred, 12, Cavendish Park, Barrow-in-Furness ... (E) Oct. 1885
Blenkinsop, John N., 38, Ashbornham Grove, Greenwich, S.E. ... (E) Oct. 1885
Blumer, Wm., 2, Ashmore Terrace, Stockton Road, Sunderland ... (S) Dec. 1886
Boddy, John, 96, Dock Street, Newport, Monmouthshire ... ... (E) Dec. 1888
Bodin, Lauritz M., 27, Argyle Square, Sunderland ... (E & SUR) Dec. 1889
Bone, W. J., 61, Linskill Terrace, North Shields ... ... (S) Dec. 1884
Bonnyman, James Smith, 13, Ryder Street, Canton, Cardiff ... (E) Nov. 1889
Boolds, Jas. H., c/o Messrs. Raylton Dixon & Co., Cleveland Shipyard, Middlesbrough ... ... (S) Oct. 1886
Booth, Edward Spence, c/o C. Furness, Esq., 85, Water Street, Boston, U.S. America ... ... (E) Oct. 1889
Booth, John William, Union Foundry, Rodley, near Leeds ... (E) April 1892
Borowski, G., 11 Lodge, 25, Taigovaja Street, St. Petersburg, Russia ... ... (E) Oct. 1885
Bosi, Guiseppe, 157, Roker Avenue, Sunderland .. .. (E & NA) Jan. 1894
Boyd, Wm., North House, Long Benton, Newcastle-on-Tyne ... (E) Nov. 1884
Boyt, John T., 204, South 3rd Street, Philadelphia, Pa., U.S.A. ... (E) Nov. 1893
Bramwell, Balfour, c/o Messrs. Harland & Wolff, Engine Works, Belfast ... ... (E) { Graduate, Nov. 1886 / Member, Nov. 1887 }
Brankston, R. T., 36, Hawthorn Street, Newcastle-on-Tyne ... (E) Nov. 1884
Broadbent, Frank, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-on-Tyne ... ... (E E) Nov. 1893
Brown, Eugene, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-on-Tyne ... ... (E E) Feb. 1886
Brown, James, c/o Sociedad Anonima, de los Astilleros del Nervion, Bilbao, Spain ... ... (E) Mar. 1891
Brown, Robson, 1, Belle Vue Terrace, Tyne Dock ... ... (E) Nov. 1889
Brown, T. R., 110, Roker Avenue, Sunderland ... (E) { Graduate, May 1885 / Member, Oct. 1886 }
Brown, William, c/o Messrs. Siemens Brothers & Co., Woolwich ... (E) April 1887
Browne, Sir B. C., Westacres, Benwell, near Newcastle-on-Tyne (C E) Jan. 1885
Bruce, William ... ... (S) { Graduate, Nov. 1891 / Member, Mar. 1893 }
Bryson, John Joshua, 58, Mount Pleasant, Barrow-in-Furness ... ... (E) { Graduate, Feb. 1889 / Member, Dec. 1892 }
Buchanan, A., Michaelson Villa, Barrow-in-Furness ... ... (S) Nov. 1884
Buchanan, John H., Oswald Chambers, 5, Oswald Street, Glasgow (SUR) Oct. 1888
Buckland, H. B., Baltic Chambers, Quayside, Newcastle-on-Tyne (E) Nov. 1885
Bull, John Catharinus, 29, Bexley Road, Erith, Kent ... ... (E) Oct. 1892
Bulmer, John, 1, Graingerville North, Newcastle-on-Tyne ... (E) Mar. 1886
Bulmer, John George, 34, Brighton Grove, Newcastle-on-Tyne ... (E) May, 1894
Burdon, J. G., Endfield, Newcastle-on-Tyne .. .. (E) Nov. 1884
Burnett, Norman, Watergate Buildings, Newcastle-on-Tyne ... (E) Oct. 1891
Bushell, Chas. A., 1 Benton Terrace, Newcastle-on-Tyne (N A & SUR) Nov. 1893
Butterfield, George, 30, John Candlish Road, Millfield, Sunderland Nov. 1884

ELECTED.

C.

Calvert, Geo. A., Wellington Villa, St. Luke's, Cork ... ... (E) Nov. 1893
Cama, Nusserwanji Bomanji, Sleaton Road, Tardeo, Bombay, British India ... ... (E) Dec. 1888
Cameron, Angus, c/o James Laing, Esq., Deptford Yard, Sunderland (S) Nov. 1892
Cameron, David, 11, Graham Place, Dundee ... ... (E) April 1891
Cameron, Henry, Hazlebank, Trinity, Edinburgh ... ... (E) Oct. 1892
Campbell, J. Jennings ... ... (E) Oct. 1888
Campbell, Thomas, 2, St. John's Terrace, Jarrow-on-Tyne... ... (S) Mar. 1894
Cannell, Frank, Messrs. H. Parry & Son, Lisbon ... ... (E & S) Nov. 1887
Cargey, D. J., Somerville House, Forest Hall, Northumberland ... (E) Nov. 1891
Carruthers, Frank, 27, Fenham Road, Newcastle-on-Tyne... ... (E) Nov. 1893
Carstons, Samuel, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark ... ... (S) Dec. 1887
Casey, James, 10, Philpot Lane, London, E.C. ... ... (E) Nov. 1891
Cay, Arthur, Messrs. Cay, Hall, & Co., Quayside, Newcastle-on-Tyne ... ... (E) Nov. 1884
Ceuvel, John L., Kantoor, Gebouw, Amsterdam ... ... (E) Mar. 1886
Chandler, Noel, Messrs. Bumsted & Chandler, Cannock Chase Engine Works, Hednesford, Staffordshire ... ... (E) Oct. 1891
Chapman, Abel, Capt., Belle Vue, Low Fell, Gateshead-on-Tyne... (E) Nov. 1884
Chapman, Harry Reynolds, Messrs. Clarke, Chapman, & Co., Gateshead-on-Tyne ... ... (E) Mar. 1893
Chapman, Hedley, 147, Park Road, Newcastle-on-Tyne ... ... (E) Feb. 1886
Charlton, Henry, 1, Millfield Terrace, Gateshead-on-Tyne... ... (E) Nov. 1884
Charlton, R. B., Jun., Manors Railway Station Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
Charlton, T., 25, Lincoln Street, Gateshead-on-Tyne ... ... (E) Nov. 1884
Charlton, Thomas, The Cedars, Millhill, West Cowes, Isle of Wight (E) Nov. 1890
Chicken, Thomas, c/o Messrs. Newport Engineering and Ship Repairing Co., Newport, Monmouth ... ... (E) Oct. 1892
Chisholm, Alexander, 2, Kent Villas, Kent Street, Jarrow-on-Tyne (S) Mar. 1893
Christie, C. A., c/o Messrs. Manchester Ship Canal, Pontoons & Dry Dock Co., Mode Wheel, Manchester ... ... (E) Nov. 1884
Christie, C. J. D., Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Christie, J. D., 4, Colbeck Terrace, Tynemouth ... ... (S) Nov. 1884

ELECTED.

Cooper, Nusserwanji Naoroji, Indo-China Mills, Dader, Sivri, Bombay, India ... ... (E) Oct. 1889
Cooper, William, Baltic Chambers, Quayside, Newcastle-on-Tyne (E) Feb. 1888
Cooper, W., Jun., 11, Ridley Place, Newcastle-on-Tyne (E) { Graduate, Nov. 1890 / Member, Jan. 1894
Coote, Arthur, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884
Copeman, William C. J., 10, Brinkburn Terrace, South Shields ... (E) Oct. 1892
Cornish, H. P., 396, Glossop Road, Sheffield ... ... (E) Oct. 1888
Couche, Henry Drew, c/o Messrs. J. & G. Thompson & Co., Ship Drawing Office, Clydebank, Glasgow ... ... (S) Oct. 1891
Courtier-Dutton, W. T., British Corporation Registry of Shipping, 69, St. Vincent Street, Glasgow ... ... (S SUR) April 1890
Cowens, William Edward, c/o Messrs. John Abbot & Co., Gateshead-on-Tyne ... ... (E) Dec. 1889
Craggs, Ernest H., Messrs. R. Craggs & Sons, Middlesborough ... (S) Oct. 1888
Craig, John C., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E SUR) Oct. 1890
Craig, Robert, Pageland House, Grange Road, West Hartlepool ... (E) Nov. 1892
Crawford, Jas., 9, Custom House Court, Quayside, Newcastle-on-Tyne ... ... (S SUR) Nov. 1886
Crawford, W. A. F., Westminster Chambers, 9, Victoria Street, London, S.W. ... ... (E) Nov. 1884
Cross, Wm., 24, Windsor Terrace, Newcastle-on-Tyne ... ... (E) Mar. 1886
Cruddas, W. D., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick, Newcastle-on-Tyne ... ... (E) Dec. 1884
Cruickshank, Alexander, 54, Tennant Street, Hebburn-on-Tyne ...(SUR) Mar. 1892
Cumming, Alexander, 20, Lorne Terrace, Sunderland ... ... (E) Nov. 1891
Cummins, W. R., 6, Roseangle, Dundee ... ... (E) Nov. 1884

D.

Dadd, Edward Martin, c/o Messrs. The Oriental Steamship Co., 84, Leadenhall Street, London, E.C. ... ... (E) Mar. 1892
Dalrymple, Wm., 14, Brinkburn Terrace, South Shields ... ... (E) Dec. 1886
Daniel, Alfred John ... ... (S) Nov. 1893
Darling, W. J., Lloyd's Register of Shipping, Dock Chambers, Barry ... ... (S) April 1887
Darney, John, c/o Messrs. Short Bros., Pallion, Sunderland ... (S) Nov. 1884
Davie, Albert, c/o Messrs. W. Denny & Bros., Leven Shipyard, Dumbarton, N.B. ... ... (E) { Graduate, Feb. 1886 / Member, Oct. 1887
Davis, Thos. Wilfrid, Birkenfeld, Bromley, Kent ... (E) { Graduate, Jan. 1891 / Member, Mar. 1894
Davison, A. J., Rosedale, Wallwood Road, Leytonstone, Essex ... (E) Oct. 1888
Denny, Archibald, c/o Messrs. W. Denny & Bros., Dumbarton ... (S) Dec. 1891
De Rusett, Edwin W., Warden House, Percy Park Road, Tynemouth ... ... (S) Nov. 1890
Dick, Francis, 6, Gladstone Street, Sunderland ... ... (E) Nov. 1885
Dick, F. W., c/o Messrs. Palmer's Shipbuilding Co., Jarrow-on-Tyne ... ... (I & S M) Oct. 1891

ELECTED.

Dickie, James, 426, Mississippi Street, Potrero, San Francisco, California, U.S.A. ... ... (S) Mar. 1894

Dickinson, F. T., 23, Park Place W., Sunderland ... (E) { Graduate, May 1885; Member, Oct. 1886 }

Dickinson, James, The Oaklands, Sunderland ... ... (E) Nov. 1884

Dickinson, John, Park House, Sunderland ... ... (E) Nov. 1884

Dickinson, R. E., c/o Messrs. The Bowling Iron Co., Bradford, Yorkshire ... ... (E) April 1889

Dickinson, W., Park House, Sunderland ... ... (E) Nov. 1884

Dietze, F. G., Hamburg South American Steam Ship Company, Hamburg .. .. (E) Nov. 1893

Dixon-Brown, L. D., Unthank Hall, Haltwhistle ... ... (S) Nov. 1886

Dixon, James, Wincombles, Walker-on-Tyne .. .. (S) Dec. 1893

Dixon, John Rochester, 79, Osborne Road, Newcastle-on-Tyne ... ... (E) { Graduate, Oct. 1887; Member, Feb. 1893 }

Dixon, Sir Raylton, Cleveland Shipyard, Middlesborough ... (S) Feb. 1888

Dixon, William, Heaton Hall Road, Heaton, Newcastle-on-Tyne ... (E) Nov. 1893

Dobson, William, Shipbuilder, Walker-on-Tyne ... ... (S) Nov. 1888

Donald, George Gray, 2, South Preston, North Shields ... ... (E) Oct. 1890

Donald, James, 48, St. Luke's Terrace, Pallion, Sunderland ... (S) Nov. 1884

Donkin, George, St. Andrew's Engine Works, Newcastle-on-Tyne (E) Oct. 1892

Donovan, J. W., 5, Ash Place, Newcastle Road, Sunderland ... (E) April 1885

Douglas, John F., c/o Messrs. Ramage & Ferguson, Leith ... ... (E) Jan. 1888

Douglass, William, Globe Iron Works, Winlaton-on-Tyne... ... (E) Nov. 1893

Dowson, Chas., 21, Croft Terrace, Jarrow-on-Tyne... ... ... (E) Dec. 1885

Doxford, Albert Ernest, B.A., 2, West Lawn, Sunderland (E) { Graduate, Oct. 1890; Member, Nov. 1893 }

Doxford, Charles D., Bainbridge Holme, Tunstall Road, Sunderland (S) Nov. 1884

Doxford, R. P., Pallion Engine Works, Sunderland ... ... (E) Nov. 1884

Doxford, W. Theodore, Pallion Shipyard, Sunderland ... ... (S) Nov. 1884

Drake, William Edward, 7, Rodwell Terrace, Weymouth ... .. (E) Feb. 1893

Drakenberg, J. A., 73, Nybrogatan, Stockholm, Sweden ... ... (E) Feb. 1886

Duckitt, Jno., 4, St. Nicholas' Buildings West, Newcastle-on-Tyne (E) Nov. 1884

Dudgeon, F. S., 30, Great St. Helens, London, E.C. ... ... (E) Feb. 1885

Dugdale, William H., Green Bank, Jarrow-on-Tyne ... ... (S) Mar. 1894

Duguid, Robert, 108, Byker Street, Walker-on-Tyne ... ... (S) Oct. 1892

ELECTED.

Egan, James, Young Street, West Hartlepool ... ... (E) Dec. 1893

Elder, Edward, Loudon House, Jarrow-on-Tyne ... (S) { Graduate, Nov. 1890 / Member, Oct. 1892

Elliot, Henry ... ... (E) May 1891

Ellis, Robert Elwood, Messrs. Cumming & Ellis, Inverkeithing, Fife ... ... (S) Feb. 1891

Eltringham, Joseph T., Stone Quay, South Shields ... ... (S & B B) Oct. 1889

English, Thos. (Lieut.-Col.), Messrs. Palmer's Shipbuilding & Iron Co., Jarrow-on-Tyne ... ... (E) Oct. 1890

Erdtman, Herman, North-Eastern Engine Works, South Docks, Sunderland... ... ... (E) Nov. 1893

Eshelby, William, 13, Brankingham Terrace, Norton Road, Stockton-on-Tees ... ... (E) Feb. 1888

Evans, Charles ... ... (E) Mar. 1891

Evans, Lewis, c/o Ralph Carr, Esq., Maritime Buildings, King Street, Newcastle-on-Tyne ... ...(SUR) Dec. 1890

Evans, William, Superintendent Engineer, Caerphilly, near Cardiff (E) Nov. 1889

Ewen, Alex., St. Mary's Island, Whitley-by-the-Sea... (E) { Graduate, Oct. 1891 / Member, Jan. 1894

F.

Farina, A. J., 63, Quayside, Newcastle-on-Tyne ... ... (E) Nov. 1884

Farrar, Harrie Crawhall, 18, Gladstone Street, Hartlepool ... (S) Nov. 1893

Faruffini, Capt. M. C., c/o Connitato Pei Designa delle Navi Ministero dilla Marina, Rome, Italy ... ... (N A) Dec. 1888

Feldtmann, H., Surveyor to Bureau Veritas, Bergen, Norway ... (E) Jan. 1889

Fenwick, James, B.Sc., C.E., 19, Bridge Street, Sydney, New South Wales ... ... (E) Oct. 1892

Ferrier, Robert M., B.Sc., Durham College of Science, Barras Bridge, Newcastle-on-Tyne ... ... (E) Nov. 1892

Filley, George Frederick, 247, Dumbarton Road, Glasgow ... (S) Nov. 1891

Findlay, John Taylor, 14, Nelson Street, Sunderland ... ... (S) Feb. 1890

Fish, Thomas Wilson, Lloyd's Register of Shipping, Glasgow ... (SUR) May 1892

Fleming, Charles Edward, 71, Elswick Road, Newcastle-on-Tyne (E) Nov. 1884

Fletcher, James, 11, Ibrox Place, Whitefield Road, Ibrox, Glasgow (E) Dec. 1885

Fletcher, Robert, Walker Forge, Walker-on-Tyne ... ... (F M) Dec. 1886

Flohr, Justus, Elisabethstrasse 10, Stettin, Germany ... ... (E) Oct. 1886

Foley, Nelson, Villa Beatrice, Parco Griffeo, Naples, Italy ... (E) Nov. 1884

Foley, Wm. C. le B., 1,705, Oxford Street, Philadelphia, U.S.A. ... ... (S) { Graduate, Nov. 1887 / Member, Oct. 1892

Ford, David, c/o Mr. Gibson, 1, Jamaica Street, Glasgow ... ... (E) May 1891

Forster, William, c/o Messrs. Dixon, Robson, & Co., 2, Collingwood Street, Newcastle-on-Tyne ... ... (E) Mar. 1890

Foster, Henry, Newburn Steel Works, Newburn-on-Tyne... ... (E) April 1885

Fothergill, J. R., 1, Bathgate Terrace, West Hartlepool ... ... (C E) Mar. 1886

Fowell, Ridley, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ...(S & E SUR) Feb. 1893

Fowling, Charles, Lloyd's Register of Shipping, Dock Office Buildings, West Hartlepool ... ... (S) Nov. 1892

Fownes, Henry, Tyne Forge, Ouseburn, Newcastle-on-Tyne ... (F M) Nov. 1884

Fox, Samson, Messrs. The Leeds Forge Co., Leeds (*Life Member*) (E) Dec. 1887

ELECTED.

Franki, J. P., c/o Messrs. Morts Dry Dock and Engineering Co., Sydney, N.S.W., Australia ... ... (E) Jan. 1886
Fraser, John Imbrie, 13, Sandyford Place, Glasgow... ... ... (E) Oct. 1891
Fraser, Thomas S., Messrs. E. Scott, Mountain & Co., The Close, Newcastle-on-Tyne ... ... (E E) Jan. 1894
Freeman, Alfred Isaac, 2, Regent Terrace, Newcastle-on-Tyne ... ... (E) { Graduate, Dec. 1890; Member, Nov. 1893 }
Furneaux, J. B., Victoria Engine Works, Gateshead-on-Tyne ... (E) Nov. 1885
Furse, Fred., Villa Schlaepfer, Capodimonte, Naples ... ... (S) April 1887

G.

Gad, Oscar, Detpford Yard, Deptford, Sunderland... ... ... (S) Nov. 1893
Gannaway, H. G., 11, Kent Street, Jarrow-on-Tyne ... ... (S) Nov. 1884
Garthwaite, John R., c/o Messrs. R. Ropner & Sons, Stockton-on-Tees (S) May 1889
Gayner, Robt. H., Jun., Beech Holm, Sunderland ... (E) { Graduate, Mar. 1886; Member, Oct. 1888 }
Gearing, Ernest George, Fairlie House, Hyde Park Road, Harrogate (E) Dec. 1892
Geddes, Christopher, 23, Brunswick Street, Liverpool ... ... (E) Oct. 1888
Gibson, H., 162, Roker Avenue, Monkwearmouth, Sunderland ... (S) Nov. 1884
Gibson, John W., 1, Bellerby Terrace, West Hartlepool ... ... (B B) Nov. 1891
Gibson, W. H., 37, Tatham Street, Sunderland ... ... (E) Nov. 1884
Glover, Terrot, 6, Azalea Terrace, Sunderland ... ... (E) Mar. 1886
Gordon, William James, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1887
Gordon, William Leslie, Invermark, Broughty Ferry, N.B. ... (E) April 1893
Graham, Edwin, Messrs. Osbourne, Graham, & Co., Hylton, Sunderland ... ... (S) Nov. 1884
Graham, Wm., Ford Lodge, South Hylton, near Sunderland ... (S) Nov. 1884
Graham, William, West House, Tynemouth ... ... (S) Oct. 1891
Graham, William, Los Astilleros del Nervion, Bilbao, Spain ... (S) April 1893
Gravell, John, Custom House Court, Quayside, Newcastle-on-Tyne (N A SUR) Nov. 1884
Gray, A., 17, Belgrave Terrace, Newcastle-on-Tyne... ... ... (E) Nov. 1888
Gray, George, 6, Salem Hill South, Sunderland ... ... (E) Feb. 1888
Gray, Harry, 19, St. George's Terrace, Jesmond, Newcastle-on-

ELECTED.

H.

Hake, G. A., 29, Rothbury Terrace, Heaton, Newcastle-on-Tyne ...(SUR) Oct. 1888
Hall, Edward, c/o Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain ... ... (S) Nov. 1885
Hall, J. Percy, Carville, Laurie Park Road, Sydenham, London, S.E. (E) Oct. 1885
Hall, John W., c/o Messrs. John Scott & Co., Abden Works, Kinghorn, N.B. ... ... (S) Oct. 1887
Hall-Brown, E., c/o Messrs. Hall-Brown, Buttery, & Co., Helen Street Engine Works, Govan, Glasgow... ... ... (E) Nov. 1888
Halley, David, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark (*Life Member*) ... ... (E) Feb. 1887
Hamilton, John, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Nov. 1886
Hamilton, R. R., c/o Messrs. Maudslay, Sons, & Field, Westminster Bridge Road, Lambeth, London ... ... (E) Nov. 1884
Hammar, Hugo G., Bureau of Construction and Repairs, U.S. Navy Yard, Brooklyn, New York, U.S.A. ... ... (S) Nov. 1890
Harding, J. C., 4, Queen's Road, Erith, Kent ... ... (E) Nov. 1884
Harkness, Richard, 8, Grenville Terrace, Grange Road, West Hartlepool ... ... (S SUR) Nov. 1884
Harlow, F., 15, Clayton Park Square, Newcastle-on-Tyne... ... (E) Nov. 1884
Harman, Bruce, c/o Messrs. A. & W. Smith & Co., Eglington Engine Works, Glasgow .. .. (E) Oct. 1886
Harper, J. H., 1, Beaumont Street, North Shields ... ... (E) Jan. 1885
Harris, Anthony, c/o Messrs. Copley, Taylor, & Co., Engineers, Middlesborough ... ... (E) Mar. 1892
Harrison, Alfred, Scotia Engine Works, Sunderland ... ... (E) Oct. 1889
Harrold, Alexander, 26, Park Road, Newcastle-on-Tyne .. ... (E) Nov. 1884
Harrold, F., 14, Rowell Street, Hartlepool ... ... (E) Nov. 1888
Hartness, J., East Boldon, near Sunderland ... ... (E) Nov. 1884
Harvey, John W. J., 1, Richmond Villa, Chertsey Road, Bristol ... (E) Feb. 1889
Havelock, Michael, G, Exchange Buildings, King Street, Newcastle-on-Tyne ... ... (E) Dec. 1887
Head, Archibald P., 47, Victoria Street, London, S.W. (E) { Graduate, Nov. 1884 / Member, Oct. 1887 }
Headlam, Robert, New Park Terrace, Hartburn Lane, Stockton-on-Tees ... ... (E) Nov. 1886
Heck, John H., Lloyd's Register of Shipping, Newport, Monmouthshire ... ... (S SUR) Nov. 1885
Henderson, Alex., c/o Messrs. Empreza, Nacional, De. Nav. D'Vapor, Lisbon .. .. (E) April 1893
Henderson, A. M., 3, Greatham Terrace, West Hartlepool ... (E) Nov. 1890
Henderson, George, 54, Westmorland Road, Newcastle-on-Tyne ... (E) Nov. 1884
Henderson, Robert, 30, Lovaine Crescent, Newcastle-on-Tyne ... (S) Nov. 1884
Henshall, Samuel, 6, Hume Street, Millfield, Sunderland (S) { Graduate, May 1885 / Member, Jan. 1894 }
Hepburn, Alfred, Northumberland Forge, Wallsend-on-Tyne ... (F M) Dec. 1890
Hepple, William, Slipway, South Shields ... ... (E & S) Oct. 1885
Hepple, William Thos., Messrs. Hepple & Co., Engineers, Wapping Street, South Shields ... ... (E) Dec. 1893
Hildrey, A. J., 11, Chester Street, Sunderland ... ... (S) Nov. 1884
Hill, Alfred William, Otterburn Terrace, Newcastle-on-Tyne ... (I M) Oct. 1891

ELECTED.

Hill, Maxwell, 1, St. Nicholas' Buildings, Newcastle-on-Tyne ... (S) Nov. 1884
Hills, Charles Henry, Anglesey Copper Works, Walker-on-Tyne ... (E) Nov. 1889
Hindson, William, Bensham Lodge, Gateshead-on-Tyne ... ... (E) Nov. 1884
Hindson, William Forster, 7, Elysium Lane, Bensham, Gateshead-on-Tyne... ... ... (E) { Graduate, Nov. 1891; Member, Nov. 1892
Hines, William, R.N., 57, St. Andrew's Road, Southsea ... ... (E) Mar. 1890
Hirst, Richard, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ... (E SUR) Nov. 1885
Hodge, Rowland F. W., Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne... ... ... (S) Dec. 1890
Hogg, James, 8, Lovaine Terrace, North Shields ... ... (B F) Nov. 1889
Hök, Wilhelm, Deptford Shipyard, Sunderland ... ... (S) Oct. 1886
Holbrook, Thomas, 22, St. Hilda Street, Hartlepool ... ... (E) Nov. 1893
Hollis, Henry William, Whitworth House, Spennymoor ... ... (I M) Oct. 1891
Holmes, John H., Portland Road, Newcastle-on-Tyne ... ... (E) Jan. 1888
Homji, A. C. N., 13, Trinity Street, Dhobie, Talao, Bombay, India (E) Nov. 1884
Hooper, Ernest, 23, Whitehall Terrace, Sunderland ... ... (E) Nov. 1885
Hopkinson, Frank A., c/o Messrs. J. Hopkinson & Co., Huddersfield (E) Dec. 1891
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
Hunter, J. W., Pendleton House, Stockton Road, Sunderland ... (E) May 1885
Hunter, Summers, c/o Messrs. N.E. Marine Engineering Co., Northumberland Engine Works, Wallsend-on-Tyne ... ... (E) Nov. 1885
Hutchinson, C. W., 6, Park Parade, Westmorland Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Hutchinson, Wesley, B.A., 6, Park Parade, Newcastle-on-Tyne ... (E) Oct. 1891
Hutchison, J., Board of Trade Offices, Middlesborough ... ...(SUR) Dec. 1891
Hutchison, Thomas Allan, 22, Wharncliffe Street, Newcastle-on-Tyne ... ... (S) Nov. 1891

I.

Inglis, John, c/o Messrs. Hawthorn & Co., Leith ... ... (S) April 1887
Inglis, John, Jun., Pointhouse Shipyard, Partick, Glasgow ... (E) Oct. 1886
Inman, Douglas S., 17, Wandsworth Road, Heaton, Newcastle-on-Tyne ... ... (E) Oct. 1892
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland (E) Nov. 1884

ELECTED.

John, Edmund, Barry Dock, Cardiff ... ... (E) Dec. 1889
Johnson, Alexander, 34, Cardigan Terrace, Heaton, Newcastle-on-Tyne ... ... (E) Feb. 1892
Johnson, Johan, 7, Vestra Hamngaten, Gothenburg, Sweden ... (S) May 1885
Johnson, T. Allan, Dry Docks, Passage West, Cork ... ... (S) Nov. 1884
Johnstone, William, Lloyd's Register of Shipping, Barrow-in-Furness ... ...(SUR) Nov. 1884
Joicey, Jacob G., Forth Banks West Factory, Newcastle-on-Tyne (E) Jan. 1889
Jones, George, c/o Messrs. W. Gray & Co., West Hartlepool ... (S) Oct. 1888
Jones, Morlais G., 6, Delahay Street, Westminster, London, S.W....
Jorgenson, F., Inspector to Austrian Lloyd's, Constantinople ...(SUR) Nov. 1888

K.

Keene, H. R., Lloyd's Register of Shipping, Exchange Buildings, Middlesborough ... ... (E) { Graduate, May 1885; Member, April 1887 }
Kelsey, William, 4, Lily Avenue, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1893
Kendall, Stonard O., c/o J. Gravell, Esq., Bureau Veritas, Custom House Court, Quayside, Newcastle-on-Tyne ... ... (SUR) Mar. 1891
Kerfoot, James, 7, Queen's Terrace, Jesmond, Newcastle-on-Tyne (E) Oct. 1892
Kilvington, W., Northumberland Engine Works, Wallsend-on-Tyne (E) Nov. 1884
King, Donald, Engineering Department, Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain ... ... (E) Jan. 1890
King, John, 18, Mather Street, Newcastle-on-Tyne ... (S) { Graduate, Dec. 1890; Member, Oct. 1892 }
Kirkaldy, John, 40, West India Dock Road, London ... ... (E) Nov. 1885
Kitching, J. F., 4, Hart Road, West Hartlepool ... ... (E) Nov. 1890
Knaffl, Alvis, c/o Norddeutscher Lloyd, Bremerhaven ... ... (E) Mar. 1893

L.

Laidley, R. W., 56, Pitt Street, Sydney, N.S.W., Australia ... (E) April 1887
Laing, Andrew, Fairfield Works, Govan, Glasgow ... ... (E) Oct. 1892
Laing, Arthur, Deptford Shipyard, Sunderland ... ... (S) Nov. 1884
Laing, Jas., Jun., Deptford Yard, Sunderland ... ... (S) Nov. 1884
Laing, John, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Larkin, James, Simonside Terrace, East Jarrow-on-Tyne ... ... (E) Nov. 1884
Laurie, Leonard George, Newport, Monmouthshire ... ... (E) Oct. 1891
Lewis, R. A., Newburn Steel Works, Newburn-on-Tyne ... ... (E) Nov. 1884
Liddell, J., c/o Messrs. Denny & Co., Engine Works, Dumbarton... (E) Nov. 1884
Lindfors, Hugo, 16, Alexandersgatan, Helsingfors, Finland ... (S) May 1889
Lineham, Wilfrid J., Jesmond, Leyland Road, Lee, London, S.E. (E) Oct. 1890
List, John, Orchard House Works, Blackwall, London, E. ... (E) April 1891
Littleboy, Chas. Wm., 2, Lorne Terrace, Stockton-on-Tees ... (S) Oct. 1887
Livingston, Thos. L., Dunedin House, Jarrow-on-Tyne ... ... (S) Nov. 1884
Lohmeyer, H., 43, Crown Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Long, A. E., 124, Albert Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Lowdon, David, Barry Dry Dock Co., Barry Dock, Cardiff ... (E) May 1894
Lowdon, John, Messrs. Barry Graving Dock and Engineering Co., Limited, Barry Dock, near Cardiff ... ... (E) Dec. 1891

ELECTED.

M.

MacColl, Hector, Strandtown, Belfast ... ... (E) Dec. 1890
Maccoy, John, 55, Larkspur Terrace, Newcastle-on-Tyne ... ... (E) Feb. 1886
MacDonald, David R., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Newcastle-on-Tyne ... ... (S) Nov. 1891
Mace, W., 253, Albert Road, Jarrow-on-Tyne ... ... (E) Jan. 1886
Macfarlane, Andrew, 18, John Street, Sunderland ... ... (E) Dec. 1890
MacGregor, John, 2, Michaelston Villas, Barrow-in-Furness ... (E) Mar. 1888
MacHaffie, John, 635, Terrace Place, Schenectady, New York, U.S.A. (E) Dec. 1885
Mackay, William, Bennie Place, Renfrew ... ... (S) Mar. 1892
Macmillan, Walter ... ... (E) May 1891
Macoll, D. C., 6, Gosforth Street, Monkwearmouth, Sunderland... (S) Nov. 1884
Macoll, Hugh, 4, Azalea Terrace North, Sunderland (*Life Member*) (S) Nov. 1884
Manaira, Guiseppe, 4, Salita S Gerslamo, Genoa, Italy ... (E & N A) Nov. 1893
Marlborough, Richard, 44, Muirpark Gardens, Partick, Glasgow... (S) Nov. 1884
Marr, James, 6, Ash Place, Sunderland ... ... (S) Nov. 1884
Marshall, F. C., 38, Percy Gardens, Tynemouth ... ... (E) Nov. 1884
Marshall, Frank T., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) {Graduate, Jan. 1885 / Member, Oct. 1888}
Marshall, R. J., 51, Larkspur Terrace, Jesmond, Newcastle-on-Tyne (E) Mar. 1887
Mastaglio, W. D., 65, Warrington Road, Newcastle-on-Tyne ... (E) Nov. 1885
Mather, Charles, 44, Warrington Road, Newcastle-on-Tyne ...(SUR) Oct. 1888
Matheson, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Dec. 1889
Matthews, A., Waterloo Road, Blyth ... ... (S) Nov. 1884
Matthews, Jas., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle-on-Tyne ... ... (E) Oct. 1886
Mavor, Alfred E., Victoria Mansions, 32, Victoria Street, London, S.W. ... ... (E E) Feb. 1890
McDougall, Neil, Managing Director British Steam Users' Insurance Society, Ld., 4 & 5, Victoria Buildings, Manchester ... (E) Mar. 1890
McGlashan, Arch., Beechcroft, Clifton Avenue, West Hartlepool (S) Nov. 1885
McIlvenna, J. G., c/o Messrs. The Tyne Pontoon and Dry Docks Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
McKay, Jno., 19, Victoria Avenue, Whitley-by-the-Sea ... ... (E) Nov. 1884
McLean, Robert M., Flinton Hill, Sunderland (S) Nov. 1893

ELECTED.

Miller, Thomas B., 28, Mount Stuart Square, Cardiff (E) {Graduate, Nov. 1886 / Member, Oct. 1888}

Mills, John, c/o Messrs. Greenock Steam Shipping Co., Greenock ... ... (E) Feb. 1888

Mills, William, East Boldon, near Sunderland ... ... (E) Feb. 1890

Milne, W. J., Welbeck Road, Walker-on-Tyne ... ... (S) Nov. 1884

Milton, J. T., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Nov. 1886

Mitchell, Chas., Jesmond Towers, Newcastle-on-Tyne ... ... (S) Nov. 1884

Moffatt, James, 7, Murray's Terrace, Belfast, Ireland (E) {Graduate, Dec. 1889 / Member, Oct. 1892}

Moffitt, George, 42, Stanley Street, Blyth ... ... (S) Oct. 1888

Moffitt, Robert, 13, Grace Terrace, Sunderland ... ... (E) Dec. 1885

Moody, Thomas V., Riding Mill, Northumberland ... ... (E) Dec. 1887

Moore, Frederick, c/o Messrs. Wilson, Sons, & Co., Ld., Pernambuco (E) Oct. 1890

Moorsom, Frederick, Queen Terrace, Seaton Carew... ... ... (S) Nov. 1893

Morgan, W. H., 22, Rochdale Street, Wallsend-on-Tyne ... ... (E) Nov. 1884

Morison, D. B., 8, Albion Terrace, Hartlepool ... ... (E) Feb. 1885

Mörk, Peter, Lennox Hotel, Dumbarton, N.B. ... ... (E) Nov. 1884

Morrison, Robt., 5, Challoner Terrace, South Shields ... ... (E) Nov. 1886

Morrison, William, Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E SUR) Oct. 1890

Morton, Richard Fraser, Lloyd's Register of Shipping, Newcastle-on-Tyne ... ... (E SUR) Oct. 1890

Mountain, William Chas., Messrs. E. Scott & Co., Close, Newcastle-on-Tyne ... ... (E E) Feb. 1889

Mudd, Thomas, Central Marine Engine Works, West Hartlepool (E) Mar. 1886

Muir, Alfred Edward, 21, Joannah Street, Sunderland ... ... (S) Mar. 1893

Muir, John ... ... (E) Oct. 1888

Muir, Robert, 11, Clarence Crescent, Whitley-by-the-Sea ... ...(SUR) Oct. 1886

Muir, Robert Home, 1, Lovaine Crescent, Newcastle-on-Tyne ... (S) Oct. 1892

Myles, David, Northumberland Engine Works, Wallsend-on-Tyne (E) Nov. 1884

N.

Nastoupil, John, Chief Engineer, Austro-Hungarian Navy, Marine Casino, Pola, Austria ... ... (E) Nov. 1890

Nevins, William, c/o S. Todd, Esq., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (E) Mar. 1894

Newbigin, Henry Thornton, 153, Weardale Street, Mount Pleasant, Spennymoor ... ... (E) Mar. 1892

Newitt, Leonard, c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne ... ... (E E) Dec. 1887

Newton, Richard, Park Square, West Hartlepool ... ... (E) April 1889

Newton, W. A., 29, Sea View Terrace, South Shields (E) {Graduate, May 1885 / Member, Oct. 1886}

Nicholls, H. E., 25, Churchill Street, Sunderland ... ... (E) Nov. 1893

Nicholson, John S., North View, Mowbray Road, Westoe, South Shields ... ... (E) Nov. 1893

Nicol, John M., 15, Linskill Terrace, North Shields ... ... (E) Nov. 1884

Nicolson, G. C., c/o Mr. Shearer, Victoria Jubilee School, Byker, Newcastle-on-Tyne ... ... (E) {Graduate, Oct. 1885 / Member, Oct. 1888}

ELECTED.

Noble, George, 40, Westgate Road, Newcastle-on-Tyne ... ... (E) May 1893
Noble, Harry, Northern Machine Tool Works, Brewery Lane, Felling-on-Tyne ... ... (E) Nov. 1888
Noble, J., 48, Marine Approach, South Shields ... ... (E) Oct. 1892
Nodder, Joseph, 503, Pitsmoor Road, Sheffield ... ... (F M) May 1893
Norman, W. S., Orchard House, Whitby, near Chester ... ... (E) Nov. 1884
Norton, Harold P., U.S.S. Concord, Bureau Steam Engineering, Navy Department, Washington, U.S.A. ... ... (E) Oct. 1890
Noton, F. R., Lloyd's Registry of Shipping, 8, Strand, Barrow-in-Furness ... ... (S) Nov. 1884
Nunes, Enrique E., Engineer, Argentine Navy, 433, Calle Ayacucho, Buenos Ayres ... ... (E) April 1891

O.

Oliver, Hedley, 6, Tower Chambers, Water Street, Liverpool ... (E) Oct. 1892
O'Neil, J. J., 2, Erith Terrace, Sunderland ... ... (E) Nov. 1884
Orde, E. L., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Newcastle-on-Tyne ... ... (E) Oct. 1887
Orlando, Chev. Giuseppe, Cantiere Navale, Fratelli Orlando, Leghorn ... ... (N A) Jan. 1893
Orr, Reginald, 18, Bulwer Street, Shepherd's Bush, London, W. ... ... (E) { Graduate, Mar. 1890; Member, Oct. 1892 }
Oxley, G., 39, Norman Terrace, Howdon-on-Tyne ... ... (S) Nov. 1884
Oxton, Walter, 96, Blackpool Street, Burton-on-Trent (E) { Graduate, Dec. 1890; Member, May 1894 }

P.

Pacey, John W., c/o Messrs. Midland Coal, Coke, & Iron Co., Apendale, near Newcastle, Staffordshire ... ... (E) Feb. 1888
Parsons, Hon. Charles A., Elvaston Hall, Ryton-on-Tyne ... ... (E E) Dec. 1887
Parsons, Harry F., Wylam House, Park View, Heaton, Newcastle-on-Tyne ... ... (E) Dec. 1890
Pascoe, J. R., Tyrmont, Woodford, Essex (*Life Member*) ... ... (S) Dec. 1889
Paton, Alexander Robert, Lloyd's Register of Shipping, West Hartlepool (SUB) Dec. 1891

ELECTED.

Phillips, Walter, 28, Brownhill Road, Catford, London, S.E. (N A & E) Oct. 1886
Phorson, P., Glen Lea, Roker, Sunderland ... ... (S) Nov. 1884
Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris ... ... (N A) Nov. 1888
Pitt, Frederick William, 15, Wilberforce Terrace, Gateshead-on-Tyne... ... ... (E SUR) Oct. 1890
Plotnicki, E. C., The Avenue, Wallsend-on-Tyne ... ... (E) Nov. 1886
Poli, Rodolfo, Chioggia, Italy ... ... (N A) Jan. 1890
Potts, Matthew, 86, Glen Terrace, Hebburn-on-Tyne ... ... (S) Dec. 1890
Potts, Robert, 11, Mount Pleasant, Deptford, Sunderland ... ... (S) Oct. 1888
Powell, James Richard, Pier Head Chambers, Cardiff ... ...(C E) May 1894
Price, F. D., 2, Bede Burn Street, Jarrow-on-Tyne ... ... (E & S) Oct. 1888
Price, John, 6, Osborne Villas, Jesmond, Newcastle-on-Tyne ... (S) Nov. 1884
Prince, Alfred, Kent Villa, Jarrow-on-Tyne ... ... (E) Nov. 1884
Pringle, Alfred, 10, Somerset Terrace, Walker-on-Tyne (S) { Graduate, Dec. 1891 / Member. Jan. 1894
Pringle, James G., 10, Somerset Terrace, Walker-on-Tyne ... ... (S) Oct. 1892
Prosser, James, 205, Albert Road, Jarrow-on-Tyne ... ... (E) Nov. 1893
Purdon, Andrew S., Fairfield Works, Govan, Glasgow ... ... (S) Oct. 1892
Purdy, A. J., Philipson Street, Willington Quay-on-Tyne... ... (E) Nov. 1884
Purves, David, Wyborne Gate, Westcliffe Road, Birkdale, Southport ... ...(SUR) Dec. 1885
Purvis, Fred. W., 5, Greatham Terrace, West Hartlepool ... ... (S) April 1893
Putnam, T., Darlington Forge, Darlington ... ...(F M) Nov. 1884
Putnam, William, Darlington Forge, Darlington ... ...(F M) Nov. 1884

Q.

Quicke, Herbert John, Summerhill House, Blaydon-on-Tyne ... (E) Feb. 1891

R.

Rae, John, 11, Gray Street, Glasgow, N.B. ... ... (E) April 1886
Ralston, G. C., The Grove, Walker Gate ... ... (E) Oct. 1887
Ramage, J. T., The Hawthorns, Ferry Road, Leith ... ... (E) April 1887
Ramage, John Anderson, 74, Glen Terrace, Hebburn-on-Tyne ... (S) Oct. 1892
Readhead, Jas., Beach View, South Shields ... ... (S) Nov. 1884
Readhead, John, Jun., 4, Salisbury Place, South Shields ... ... (E) Mar. 1886
Readhead, R., 28, Sea View Terrace, South Shields ... ... (E) Nov. 1884
Readhead, W. B., South-garth, Westoe, South Shields ... ... (S) Nov. 1886
Reavell, W., c/o Messrs. Babcock & Wilcox 147, Queen Victoria Street, London, E.C. ... ... (E) { Graduate, April 1885 / Member, Oct. 1887
Reed, Joseph, Angerton House, North Shields ... ... (E) Oct. 1889
Reed, J. W., c/o Messrs. Palmer's Shipbuilding and Iron Co., Limited, Engine Works Department, Jarrow-on-Tyne ... (E) Nov. 1884
Rennoldson, C., Messrs. J. P. Rennoldson & Sons, South Shields ... (S) Jan. 1886
Rennoldson, Jos. M., Messrs. J. P. Rennoldson & Sons, South Shields (S) Feb. 1886
Reynolds, Charles H., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker-on-Tyne ... ... (S) Mar. 1889
Reynolds, Edward, c/o Messrs. Vickers, Sons, & Co., Sheffield ... (E) Jan. 1888
Reynolds, W. G., 36, Meldon Terrace, South Shields ... ... (E) Oct. 1886
Richardson, Philip Wigham, Neptune Works, Walker-on-Tyne ... (S) Nov. 1890
Richardson, T., Jun., Hartlepool Engine Works, Hartlepool ... (E) April 1888
Richardson, Wigham, Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884

		ELECTED.
Rickaby, A. A., Bloomfield Engine Works, Sunderland	(E)	Mar. 1888
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Nov. 1884
Riley, J. H., Messrs. Riley Bros., Stockton-on-Tees	(B B)	May 1893
Rimmington, R. F., 6, Cliff Terrace, Hartlepool	(E)	Nov. 1888
Ritson, M., Lloyd's Register of Shipping, 56, Constitution Street, Leith	(E SUR)	Nov. 1884
Ritson, S. M., 18, St. Bede's Terrace, Sunderland ...	(E)	Graduate, Nov. 1887 Member, Nov. 1893
Roberts, David, 19, West Avenue, Gosforth, Newcastle-on-Tyne...	(E)	Oct. 1891
Robinson, B. A., 12, Harold Street, Sunderland	(E)	Nov. 1884
Robinson, William, 7, Choppington Street, Newcastle-on-Tyne	(E)	Graduate, May 1885 Member, April 1888
Robson, Arthur, Messrs. J. Blumer & Co., Sunderland	(S)	Dec. 1886
Robson, George, 9, Wellington Terrace, South Shields	(E)	Oct. 1889
Robson, Geo. Edward, 69, Thornton Street, West Hartlepool ...	(S)	Nov. 1893
Robson, John H., Grainger Commercial Hotel, Newcastle-on-Tyne	(E)	Nov. 1885
Robson, J. M., 4, Abbey Terrace, Gateshead-on-Tyne	(E)	Nov. 1884
Robson, M., 23, Zion Terrace, Newcastle Road, Sunderland ...	(S)	Nov. 1884
Roger, Robert, Stockton Iron Foundry, West Row, Stockton-on-Tees	(E)	Nov. 1888
Rogers, Herbert M., Laurel Bank, Bromley Common, Kent	(SUR)	April 1889
Rolf, George. Lefroy House, Newcastle-on-Tyne	(E E)	May 1892
Rolland, Alexander, Villa Ruzic, Susak, Fiume, Hungary	(E)	Mar. 1892
Rooke, Charles Bowden, Jun., St. Paul's Road, West Hartlepool...	(E)	Nov. 1889
Ropner, Robert, Jun., Stockton-on-Tees	(S)	Feb. 1886
Rose, Joseph	(E)	Oct. 1891
Ross, William, 20, Meadow Side, Dundee	(E)	May 1893
Rosser, W. D., Cardiff Pontoon Company, Mount Stuart Square, Cardiff	(S)	Nov. 1893
Rowan, Jas., 231, Elliott Street, Glasgow	(E)	Nov. 1886
Rowell, G. W., Simla House, New Benwell, Newcastle-on-Tyne ...	(E)	Feb. 1885
Rowell, H., 45, Glen Terrace, Hebburn-on-Tyne	(S)	Nov. 1884
Rusden, L., 14, Sanderson Road, Jesmond, Newcastle-on-Tyne ...	(E)	Nov. 1884
Russell, F. Herbert, Scotia Engine Works, Sunderland	(E)	Oct. 1891
Rutherford, G., Bute Dry Dock, Roath Basin, Cardiff	(S)	Oct. 1886

ELECTED.

Sawyers, John, c/o Messrs. Thos. Wilson, Sons, & Co., Hull ... (E) Oct. 1886
Schaeffer, A. G., 4, Benton Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Scotson, Alf., 22, Victoria Road, Middlesborough ... ... (S) Feb. 1887
Scotson, Wm., 78, Stafford Street, Wednesbury ... ... (E) Nov. 1884
Scott, Ernest, Close Engine Works, Newcastle-on-Tyne ... ... (E E) Nov. 1884
Scott, James, c/o Messrs. Consett Iron Co., Blackhill, Co. Durham... (E) Oct. 1892
Scott, Joseph R., 9, Queen Street, Newcastle-on-Tyne ... ... (E) Oct. 1887
Scott, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Scurlock, Thos. Henry, 12, Windsor Road, Barry, near Cardiff ... (S) Oct. 1890
Seabury, Edward, 40, West India Road, Limehouse, London, E. ... (E) Mar. 1886
Seaman, C. J., Fairfield, North Stockton-on-Tees ... ... (E) Jan. 1889
Seaton, Albert Edward, Messrs. Earle's Shipbuilding Co., Hull ... (E) Jan. 1891
Selby, Thomas, 7, Regent Square, Hartlepool ... ... (E) Nov. 1891
Sells, C. Degrave, Cornigliano, Ligure, Italy ... ... (E) Oct. 1887
Shand, H., 30, Sanderson Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Sharman, Geo. Dixon, Deptford Yard, Sunderland ... ... (S) Nov. 1893
Sharp, A. E., 16, Bede Burn Road, Jarrow-on-Tyne ... ... (E) Nov. 1884
Sharp, Mark, 144, Albert Road, Jarrow-on-Tyne ... ... (E) Dec. 1889
Shaw, Jas., c/o Messrs. Hunting & Pattison, Exchange Buildings, Quayside, Newcastle-on-Tyne ... ... (E) Jan. 1885
Sheriff, Thomas, c/o Messrs. Robert Mackill & Co., 29, Waterloo Street, Glasgow ... ... (E) April 1890
Shevill, W. H., 5, Avenue Terrace, Sunderland ... ... (E) Nov. 1884
Short, J. Y., 49, West Sunniside, Sunderland ... ... (S) Nov. 1884
Short, Jos., 49, West Sunniside, Sunderland ... ... (S) Nov. 1884
Shotton, John W., 32, Mount Stuart Square, Cardiff ... ... (SUR) Nov. 1886
Shute, A. E.. 40, Eldon Street, Greenock, N.B. ... ... (E) Dec. 1892
Simpson, Edward, 2, Neptune Road, Wallsend-on-Tyne ... ... (S) Dec. 1890
Sinclair, R., c/o Messrs. J. Wildridge & Sinclair, Consulting Engineers, 97, Pitt Street, Sydney, N.S.W., Australia ... (C E) Nov. 1884
Sinton, John K., 26, Sandhill, Newcastle-on-Tyne ... ... (E) Nov. 1885
Sisson, Wm., Gloucester ... ... (E & N A) Oct. 1888
Sisterson, G. R., Locomotive Department, London and South Western Railway, Nine Elms, London, S.W. ... ... (E) Nov. 1884
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool ... ... (S) Nov. 1886
Skinner, Leslie, Ravensbourne Terrace, South Shields (S) { Graduate, Dec. 1886 / Member, Oct. 1891 }
Smith, C. E., 73, Thornton Street, West Hartlepool ... ... (E) Nov. 1888
Smith, Eustace, 5, Queen Street, Newcastle-on-Tyne ... ... (S) Nov. 1884
Smith, John Law, West Hartlepool Steel and Iron Works, West Hartlepool ... ... (I & S M) May 1893
Smith, L. Eustace, 22, St. Mary's Place, Newcastle-on-Tyne... ... ... (E) { Graduate, Oct. 1889 / Member, Oct. 1892 }
Smith, Malden H., c/o Col. F. J. Smith, R.E., Belmont, Ryde, Isle of Wight... ... ... (S) April 1893
Smith, R. J., Pier Engine Works, South Dock, Sunderland ... (E) Nov. 1884
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds (E) Oct. 1888
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-on-Tyne ... ... (E) April 1885
Smith, Wm., 51, Dock Street East, Sunderland ... ... (E) Nov. 1884

ELECTED.

Soliani, Nabor, Sotto Direzione Delle Costruzioni Navali del Rº Cantiere di Castellammare di Stabi, Italy ... ... (S) Jan. 1885
Sowter, Isaac G., Cleveland Shipbuilding Co., Cleveland, Ohio, U.S. America ... ... (E) Jan. 1889
Spear, John, c/o Messrs. T. Wilson & Sons, Hull ... ... (E) Oct. 1887
Spearman, Richard, c/o Messrs. The Jarrow Forge & Engineering Co., Ld., Jarrow-on-Tyne... ... ... (E) Feb. 1889
Spence, W. G., c/o George Clark, Esq., Southwick Engine Works, Sunderland (*Life Member*) ... ... (E) Nov. 1884
Spencer, J. W., Newburn Steel Works, Newburn-on-Tyne ... (E) Feb. 1885
Stafford, William, Dunston-on-Tyne ... ... (E) Nov. 1885
Stansfield, George R., 4, Beaconsfield St., Westoe, South Shields... (E) Mar. 1891
Stephenson, C., 2. Elm Terrace, The Green, Wallsend-on-Tyne ... (S) Nov. 1884
Stevenson, Wm., 6, West View, Wallsend-on-Tyne ... ... (E) Nov. 1884
Stewart, James, 31, Lily Avenue, Jesmond, Newcastle-on-Tyne .. (E) Oct. 1890
Stirling, Andrew, Jun., 1, Greenvale Terrace, Dumbarton ... ... (E) Feb. 1888
Stirzaker, J. C., 16, Grosvenor Place, Newcastle-on-Tyne ... ... (E) Nov. 1884
Stoddart, J. E., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E SUR) Oct. 1888
Stoddart, Swinton, 24, North Milburn Street, Sunderland (S) { Graduate, May 1885; Member, Nov. 1892 }
Stokoe, Thomas W., 32, Scarboro' Street, West Hartlepool ... (S) Dec. 1885
Stone, Wm., 13, Rosslyn Terrace, Sunderland ... ... Nov. 1884
Stonehouse, Andrew, Jun. ... ... (S) Oct. 1890
Strong, George Aaron, 87, West Percy Street, North Shields ... (E) Dec 1889
Summers, James, 114, Grange Road West, Middlesborough ... (E) Mar. 1889
Summersby, Robert Arthur, 4, Otterburn Terrace, Newcastle-on-Tyne ... ... (E) Oct. 1891
Surtees, Francis V., Westbourne Street, Stockton-on-Tees... ... (S) Dec. 1892
Surtees, R., Frame House, Low Teams, Gateshead-on-Tyne ... (E) Nov. 1884
Swan, A. S., Grove House, Gosforth, Newcastle-on-Tyne ... ... (S) Nov. 1888
Swan, Charles Sheriton, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne... ... ... (S) { Graduate, Nov. 1890; Member, Mar. 1894 }
Swan, H. F., North Jesmond, Newcastle-on-Tyne ... . (S) Nov. 1884
Swan, Thomas, Mayfield House, Leslie, Fifeshire ... ... Nov. 1884
Swinburne, M. W., 117, Park Road, Newcastle-on-Tyne ... (E) Nov. 1884

ELECTED.

Thompson, John Augustus, 12, London Street, Fenchurch Street, London, E.C. ... ... (E & N A) Oct. 1892
Thompson, J. L., North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Thompson, Robert, North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Thomson, James, M.A., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Ordnance Works, Elswick, Newcastle-on-Tyne (E & N A) Nov. 1890
Thorn, W. H., 5, Waterville Terrace, North Shields ... ... (E) Nov. 1884
Thornton, James, Pullington Villa, Cumberland Road, Bristol ... (E) April 1893
Tinkler, Robert Harrison ... ... (E) April 1891
Tinn, Fred. D., 2, Sunningdale Terrace, South Shields ... ... (E) Nov. 1891
Tinwell, George, General Gordon Terrace, Sunderland ... ... (E) Jan. 1889
Todd, Surtees, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884
Todd, Thomas, 19, Billiter Street, London, E.C. ... ... (E) Nov. 1885
Tone, John M. F., c/o Messrs. H. S. Edwards & Sons, High Dock, South Shields ... ... (E) { Graduate, April 1885; Member, Oct. 1887 }
Topham, Henry George, 13, Choppington Street, Newcastle-on-Tyne... ... ... (E) May 1891
Towers, Edward, Jun., 4, Latimer Street, Tynemouth (E) { Graduate, Nov. 1886; Member, Oct. 1888 }
Trail, John, 25, Sanderson Road, Jesmond, Newcastle-on-Tyne (M S) Oct. 1892
Trewent, F. J., 43, Billiter Buildings, Billiter Street, London, E.C. ... ... (S) Dec. 1884
Tulip, George, Universities Mission, Lake Nyassa, Central Africa (E) Dec. 1888
Turner, S. J., 71, Warwick Street, Heaton, Newcastle-on-Tyne ... (E) Mar. 1887
Twaddell, James L., 2, Edelweiss Terrace, Partick, Glasgow ... (S) Oct. 1891
Tweddell, R. H., Meopham Court, Gravesend, London ... ... (E) Jan. 1885
Tweedy, J., Neptune Works, Walker-on-Tyne ... ... (E) Nov. 1884
Twigden, George J., c/o Messrs. Hick Bros., Mount Stuart Square, Cardiff ... ... (E) Jan. 1890
Tyzack, George, Dean Street, South Shields ... ... (E) April 1888

U.

Ullstrom, Otto, Messrs. Crompton, Ullstrom, & Crompton, 19, Gracechurch Street, London, E.C. ... ... (S) Nov. 1884
Ulm, John, The Arsenal, Pola, Austria ... ... (E) Nov. 1885

V.

Vianson, N. E., *vid* Galcazzo Alessi 6 into 1, Genoa, Italy ... ... (E) Dec. 1885
Vick, R. W., Messrs. E. Withy & Co., West Hartlepool ... ... (S) Nov. 1888
Vivet, Leon, 12, Rue de Seine, Paris ... ... (N A) Nov. 1892

W.

Wadagaki, Yasuzo, Naval Dockyard, Yokosuka, Japan ... ... (E) Jan. 1891
Wailes, E. F., 4, St. Nicholas' Buildings, Newcastle-on-Tyne ... (N A) Nov. 1884
Wailes, T. W., Mount Stuart Dry Docks, Cardiff ... ... (E & S) Oct. 1887
Wait, Thomas Herbert, Cail's Buildings, Quayside, Newcastle-on-Tyne ... ...(C E) Dec. 1893
Wake, Tom, Church Walk, Hartlepool ... ... (E) April 1892
Walker, Archibald, Elizafield House, North Fort Street, Leith, N.B. (E) April 1887
Walker, Henry, 11, Oxford Terrace, Gateshead-on-Tyne ... ... (E E) Feb. 1893

ELECTED.

Walker, John, c/o Messrs. R. Stephenson & Co., Limited, South Street, Newcastle-on-Tyne ... ... (E & S) Nov. 1891
Wallau, J., c/o Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne (E) Nov. 1884
Walliker, J. F., Lloyd's Register of Shipping, Bute Docks, Cardiff (E) Nov. 1885
Wallis, Robert, Point Pleasant House, Wallsend-on-Tyne ... ... (E) April 1891
Walter, Max, 120B, Smidtstr, Bremerhaven ... ... (S) Feb. 1893
Walton, J. G., 26, Fenchurch Street, London, E.C. ... ... (E) Nov. 1884
Walton, Samuel, 34, Pollard Street, South Shields ... ... (E) Dec. 1893
Warburton, J., 19, Lorne Terrace, Sunderland ... ... (E) Nov. 1884
Ward, John, c/o Messrs. W. Denny & Bros., Dumbarton ... ... (S) Dec. 1891
Ward, Mark M., 76, Church Street, West Hartlepool ... ... (E) Dec. 1893
Wardale, Henry, 5, Collingwood Terrace, Gateshead-on-Tyne ... (E) Feb. 1888
Watt, Robert B., c/o Messrs. Raylton Dixon & Co., Middlesborough (S) April 1888
Watts, Philip, Elswick Shipyard, Newcastle-on-Tyne ... ... (S) Nov. 1885
Waugh, G. W., 6, Grosvenor Place, North Shields ... ... (E) May 1885
Weatherall, J., c/o Messrs. Naval Construction & Armaments Co., Barrow-in-Furness ... ... (E) { Graduate, Oct. 1885; Member, Oct. 1887
Weidemann, Nils, Det-Norske Veritas, Christiania, Norway ...(SUR) Jan. 1892
Weighton, R. L., M.A., Durham College of Science, Barras Bridge, Newcastle-on-Tyne ... ... (E) Nov. 1884
Weir, John, c/o Messrs. J. Scott & Co., Abden Works, Kinghorn, N.B. ... ... (E) Nov. 1884
Weir, William, c/o Messrs. Wigham Richardson & Co., Walker-on-Tyne ... ... (E) Nov. 1889
Welton, J. J., 12, Hendon Valley Road, Sunderland ... ... (E) Nov. 1893
West, Henry H., 14, Castle Street, Liverpool ... ... (E & N A) Oct. 1886
Westgarth, Tom, Messrs. Westgarth, English, & Co., Middlesborough (E) Oct. 1886
Westmacott, Alfred, Benwell Hill, Newcastle-on-Tyne (E) { Graduate, Dec. 1885; Member, Nov. 1892
Westmacott, P. G. B., Benwell Hill, Newcastle-on-Tyne ... ... (E) Nov. 1884
Wheeler, Oswald, c/o Messrs. Ashwall & Nesbitt, Victoria Foundry, Sycamore Lane, Leicester ... ... (E) { Graduate, Oct. 1886; Member, Oct. 1892
White, C., 13, Mosley Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
White, Ernest T., 16, Abbey Terrace, Gateshead-on-Tyne (E) { Graduate, May 1889; Member, Jan. 1894
White, R. S., Gardiner, Pollockshields, Glasgow ... ... (S) Nov. 1884

ELECTED.

Wortley, Henry B., 23, Bedford Road, Rock Ferry, Birkenhead ... ... (S) { Graduate, Jan. 1886 / Member, Nov. 1892
Wotherspoon, R., Board of Trade Offices, West Hartlepool (E SUR) April 1889
Wright, R., 5, Hawthorn Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884

Y.

Young, Andrew, 70, Falmouth Road, Heaton, Newcastle-on-Tyne ... ... (S) { Graduate, Feb. 1892 / Member, May 1893
Young, J. Denholm, 11, Grange Crescent, Sunderland ... ... (E) Oct. 1888
Younger, R., Elmire House, Heaton, Newcastle-on-Tyne ... ... (E) Nov. 1884

Z.

Zeeman, J. H., c/o Messrs. The Maas Co., Rotterdam ... ... (S) Oct. 1889

ASSOCIATES.

A.

Adam, John B., Osborne Terrace, Newcastle-on-Tyne ... ... (O) Nov. 1893
Anderson, Daniel G., Burnaby Lodge, Ryton-on-Tyne ... ... (A) Nov. 1893
Armstrong, S., 14, Victoria Place, Hartlepool ... ... (A) Nov. 1888

B.

Bacon, William Charles, Chadwick House, West Hartlepool ... (S O) Dec. 1890
Barklam, George, 167, Dudley Port, Tipton, Staffordshire ... (A) April 1888
Barr, John Smith, 5, Mosley Street, Newcastle-on-Tyne ... ... (A) Nov. 1893
Barraclough, Thomas, West Hartlepool Steam Navigation Co., West Hartlepool ... ... (S O) Dec. 1890
Barwick, J. S., Ashbrook Grange, Sunderland ... ... (S O) Nov. 1884
Bell, John Henry, 39, Albert Drive, Pollockshields, Glasgow (I & S M) Oct. 1887
Beynon, Thomas, 9, Dean Street, Newcastle-on-Tyne ... ... (E A) Oct. 1891
Bigge, C. W., Northern Counties Club, Newcastle-on-Tyne ... (A) Dec. 1889
Blacklin, Richard James, Dinsdale House, Brougham Terrace, West Hartlepool ... ... (S O) Dec. 1890
Branfoot, W. J., Messrs. Tyzack & Branfoot, 18, John Street, Sunderland ... ... (S O) Dec. 1887
Briggs, R. S., Moorlands, Sunderland ... ... (S O) Dec. 1886
Brims, D. N., 4, St. Nicholas' Buildings, Newcastle-on-Tyne ... (C) Nov. 1893
Brunton, John, 3, Prior's Terrace, Tynemouth ... ... (S O) Oct. 1886
Bullen, Tempest C., c/o Messrs. H. E. Moss & Co., K, Exchange Buildings, Newcastle-on-Tyne ... ... (S O) Nov. 1891

C.

Carnegy, Robert B., Kimberley Club, Kimberley, South Africa ... (A) Oct. 1891
Carr, Ralph, Thornleigh, Clayton Road, Newcastle-on-Tyne (A & S O) Nov. 1886
Cassap, William, 15, East Field Road, Walthamstow, Essex ... (SUR) Feb. 1890
Caws, Frank, 22, Fawcett Street, Sunderland ... ... (C E) Oct. 1892
Cohan, Edward Asher, 2, Rumford Place, Liverpool ... ... (S O) Nov. 1889
Common, Francis James, 5, Elms West, Sunderland ... (I & S M) Oct. 1887
Conner, L. R., Exchange, West Hartlepool ... ... (S O) Jan. 1891

ELECTED.

Cooper, Charles, Average Adjuster, Wellington Road, West Hartlepool ... ... (A A) April 1893
Corbitt, Michael, 1, Abbotsford Terrace, Newcastle-on-Tyne ... (R M) Jan. 1890
Coull, John, 43, Stanley Street West, North Shields ... ... (S O) Oct. 1886
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool ... ... (S O) Nov. 1888
Crosier, Edward James, 3, The Hawthorns, East Boldon ... ... (A) Oct. 1889
Culliford, J. H. W., 45, West Sunniside, Sunderland ... ... (S O) Nov. 1884

D.

Dodds, A. P., 13, Dean Street, Newcastle-on-Tyne ... ... (A) Jan. 1889
Dodds, E. F., 36, Side, Newcastle-on-Tyne ... ... (A) Nov. 1893
Dodds, John B., 36, Side, Newcastle-on-Tyne ... ... (CHEM) Oct. 1888
Dove, Edward John, 5, St. Nicholas' Buildings, Newcastle-on-Tyne Oct. 1890

E.

Eccles, Edward, Royal Insurance Buildings, Queen Street, Newcastle-on-Tyne (*Life Associate*)... ... ... (S O) Oct. 1887

F.

Furness, Christopher, M.P., Victoria Terrace, West Hartlepool ... (S O) Oct. 1888

G.

Garnett, William, LL.D., 13, Spring Gardens, London, S.W. ... Jan. 1889
Graham, Frank, Bank Chambers, Mosley Street, Newcastle-on-Tyne ... ... (E A) Nov. 1891
Greenwell, Thos. G., Sunderland ... ... (S O) Dec. 1886

H.

Hardy, John, Jun., Brunswick Street, West Hartlepool ... ... (I M) Nov. 1893
Harland, George, 1, Westoe Crescent, South Shields ... ... (A) Dec. 1888
Hedley, John H., 10, Esplanade West, Sunderland ... ... (S) Dec. 1886
Henzell, Robert, Northern Oil Works, Close, Newcastle-on-Tyne (*Life Associate*) ... ... (A) Nov. 1893

ELECTED.

K.

Kerr, James, 18, Azalea Terrace South, Sunderland ... ... (A) Jan. 1888

L.

Lennard, William, c/o Messrs. J. M. Lennard & Sons, Middlesborough ... ... (S) Dec. 1891
Lockie, John, 4, Sanderson Road, West Jesmond, Newcastle-on-Tyne ... ...(S O) Oct. 1892
Loveridge, W. H., Albert Terrace, West Hartlepool... ... (I & S M) Oct. 1888

M.

Macarthy, George E., 9, Dean Street, Newcastle-on-Tyne ... ...(S O) Oct. 1887
Matthiessen, P. H., 25, Queen Street, Newcastle-on-Tyne ... ...(S O) Oct. 1888
Maughan, Thos., Jun., Hollyfield House, Sorley Street, Sunderland (A) Nov. 1893
Maughan, William, 13, Mosley Street, Newcastle-on-Tyne... ... (A) Feb. 1887
McIntosh, R. Y., 53, Quayside, Newcastle-on-Tyne ... ... (E A) Nov. 1891
McIntyre, John, 3, Abbotsford Terrace, Newcastle-on-Tyne ... (S O) Jan. 1885
McNabb, Thos., Cail's Buildings, Quayside, Newcastle-on-Tyne ... (S O) Nov. 1886
Metcalf, Thomas, 18, John Street, Sunderland ... ...(SUR) Jan. 1888
Milburn, J. D., Queen Street, Newcastle-on-Tyne ... ...(S O) Nov. 1884
Miller, T. R., 9, Great St. Helen's, London, E.C. ... ... (A & S O) Nov. 1884
Mitcalfe, John Stanley, Chairman of Northern Maritime Insurance Co., Maritime Buildings, Newcastle-on-Tyne ... ... (A & S O) Jan. 1892
Muir, James, 2, Dingle Lane, Liverpool ... ... (M S) Nov. 1893
Mulherion, G. F., 13, Argyle Street, Tynemouth ... ... (A) Nov. 1884
Muller, J. C. F., 28, Vieille Route, Antwerp ... ...(SUR) Feb. 1890
Murray, Matthew, The Green, Wallsend-on-Tyne ... ... (A) Nov. 1893

N.

Newby, S., c/o Messrs. Thomson & Newby, Edinburgh Chambers, 41, Fawcett Street, Sunderland ... ... (I & S M)Nov. 1884
Nicholson, John, 7, Side, Newcastle-on-Tyne ... ... (M S) Nov. 1890
Nicol, Andrew, 22, Grosvenor Road, Jesmond, Newcastle-on-Tyne (S) Oct. 1891

O.

O'Hagan, James, St. Nazaire-sur-Loire, France ... ... (A) Oct. 1888
Olsen, Hans Benedick, 70, Church Street, West Hartlepool ... (S O) Mar. 1893
Osbourne, Jas., 11, The Oaks, Sunderland ... ... (S) Jan. 1885

P.

Panton, Hugh, 38, Fawcett Street, Sunderland ... ... (I & S M) Nov. 1887
Patterson, Thos., 2, The Elms, Sunderland ... ... (S) Jan. 1885
Perry, Edwin, Queen Street, Newcastle-on-Tyne ... ... (A) Nov. 1885
Petterson, William, 7, Haldane Terrace, Jesmond, Newcastle-on-Tyne ... ... (O) Nov. 1893
Phalp, Oliver, Almora, 37, Richmond Road, Cardiff... ... ...(SUR) Feb. 1889
Pinkney, Thomas, 3, Ashbrook Terrace, Sunderland ... ...(S O) Dec. 1886
Pirrie, Robert Reid, Baltic Chambers, Quayside, Newcastle-on-Tyne (S O) Dec. 1889
Proctor, J. H., 11, Wentworth Place, Newcastle-on-Tyne ... ... (I M) Nov. 1893

ELECTED.

R.

Radloff, Captain O., Marine Superintendent, Russian Volunteer Fleet Committee, 14, Catherine Canal, St. Petersburg, Russia... ... ... (M S) Nov. 1891
Ramsay, J. W., 13, Northbrook Road, Lee, Kent ... ... (A) Feb. 1885
Reichwald, A., Lombard Street, Newcastle-on-Tyne ... ... (A) Nov. 1884
Reid, Andrew, Printer, Akenside Hill, Newcastle-on-Tyne ... Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Queen Street, Newcastle-on-Tyne ... ... (S O) Nov. 1884
Rickinson, John, 9, Church Street, West Hartlepool ... ... (S O) Nov. 1890
Robson, Frederick, 46, Dean Street, Newcastle-on-Tyne ... (S I M) Oct. 1887
Robson, Thos., Causeway House, Sunderland ... ... (S O) Nov. 1884
Runciman, John Finley, 38, Larkspur Terrace, Jesmond, Newcastle-on-Tyne ... . (M S) Nov. 1892

S.

Scholefield, A., 17, Sandhill, Newcastle-on-Tyne ... ... (S O) Nov. 1884
Scott, W. H., Messrs. Scott Brothers, Dean St., Newcastle-on-Tyne (S O) Nov. 1884
Snowdon, W. F., 32, Side, Newcastle-on-Tyne ... ... (E A) Dec. 1886
Squance, J. W., 13, The Avenue, Sunderland ... ... (M S) April 1888
Swan, Isaac J., Grove House, Gosforth, Newcastle-on-Tyne ... (S O) Feb. 1888

T.

Tate, Arthur, Bank Chambers, Sandhill, Newcastle-on-Tyne ... (O) Nov. 1893
Thompson, V. T., Baltic Chambers, Sunderland ... ... (S O) Dec. 1886
Towers, Edward, 4, Latimer Street, Tynemouth ... ... (A) Oct. 1888

W.

Wait, James, Maritime Buildings, King Street, Newcastle-on-Tyne (S O) Nov. 1884
Wait, John, 70, Broughton Road, South Shields ... ... (A) Oct. 1891
Walker, James, c/o Messrs. Gilchrist, Walker, & Co., Constantinople (S O) Mar. 1894
Wallace, Wm., 27, South Scarborough Street, West Hartlepool ... (A) Oct. 1888
Ward, Joseph, Rosehill, Howdon-on-Tyne ... ... (A) Nov. 1886
Watson, Thomas W., Gisburn House, Hartlepool ... ... (M S) Nov. 189C
Weatheral, Henry, 27, Alderson Street, West Hartlepool ... ... (A) Feb. 1893

ELECTED.

B.

Baker, Ernest, 44, Lovaine Place, Newcastle-on-Tyne ... ... (E) Nov. 1892
Barbour, John, 1, Logan Terrace, South Shields ... ... (E) Nov. 1890
Beale, Harry, Otterburn Villas, Newcastle-on-Tyne ... ... (S) Jan. 1891
Beilby, Norman Harry, 27, Eldon Square, Newcastle-on-Tyne ... (E) Dec. 1893
Bent, John Bradbury, 74, Rye Hill, Newcastle-on-Tyne ... ... (E E) May 1894
Bentham, Frederick Lister, 9, Bellegrove Terrace, Newcastle-on-Tyne... ... ... (E) Dec. 1892
Bilbrough, Kenneth L., 50, Lovaine Place, Newcastle-on-Tyne ... (E) Nov. 1891
Boswell, Cecil Robert, Northumberland Engine Works, Wallsend-on-Tyne ... ... (E) Nov. 1893
Bowden, John, Sheriff Mount, Gateshead-on-Tyne ... ... (E) Jan. 1894
Brodin, Olof, Ecfle, Sweden ... ... (S) Mar. 1890
Bryers, Charles, 10, The Avenue, Sunderland ... ... (E) Dec. 1892
Bulmer, Frederick Charles, 1, Graingerville North, Newcastle-on-Tyne... ... ... (E) May 1894
Bulmer, Septimus, 1, Graingerville North, Newcastle-on-Tyne ... (E) May 1894
Burn, Donald B., 7, The Elms West, Sunderland ... ... (S) Nov. 1893
Burnett, Jacob Edward, 10, Prior's Terrace, Tynemouth ... ... (E) Oct. 1891

C.

Cadman, C. C., 21, Shieldfield Green, Newcastle-on-Tyne ... ... (E) Nov. 1891
Calvert, T. Horsfall, 4, South Crescent, Hartlepool ... ... (E) Nov. 1891
Carpmael, Richard Herbert, 12, Grove Street, Newcastle-on-Tyne (E) Jan. 1893
Carr, Ralph, Jun., Thornleigh, Clayton Road, Newcastle-on-Tyne (E) Jan. 1894
Carter, Thomas, Jun., Belle Vue Park, Sunderland ... ... (E) Nov. 1891
Coatsworth, George S., 1, Humbleton View, Sunderland ... ... (E) Nov. 1891
Coopor, Sidney, 14, Northgate, Hartlepool ... ... (E) Nov. 1891
Coull, Alex. B., 43, Stanley Street W., North Shields ... ... (E) Feb. 1887
Cowell, Richard E., Montpellier, Sunderland ... ... (E) Dec. 1893
Crawford, J. F., c/o John Dickinson, Esq., Palmer's Hill Engine Works, Sunderland ... ... (E) Nov. 1893
Crawhall, Henry F., 58, Westmoreland Road, Newcastle-on-Tyne (E E) May 1894

D.

Davis, James Albert, 4, Dickinson Crescent, Gosforth, Newcastle-on-Tyne .. .. (S) Dec. 1892
Davison, William H. G., 49, Sanderson Road, West Jesmond, Newcastle-on-Tyne ... ... (E) Dec. 1892
Dobson, Henry James, c/o Messrs. William Dobson & Co., Walker-on-Tyne, R.S.O. ... ... (S) Oct. 1891
Donovan, John, 5, Ash Place, Sunderland ... ... (E) Dec. 1892
Duckitt, J. Brentnall, Leazes Gate Villa, Spital Tongues, Newcastle-on-Tyne ... ... (E E) Oct. 1888
Duckitt, Talbot, Leazes Gate Villa, Spital Tongues, Newcastle-on-Tyne ... ... (E E) Oct. 1891

E.

Edminson, Frank A., Otterburn Villas, Newcastle-on-Tyne ... (S) Nov. 1893

ELECTED.

F.

Fairbairn, Jas., 54, Amberley Street, Sunderland ... ... (E) May 1885
Finch, Herbert K., c/o Messrs. Blainscough Colliery Co., Coppull, Lancashire ... ... (E) Dec. 1888
Ford, Hugh M., 23, Lovaine Crescent, Newcastle-on-Tyne ... (E) Nov. 1893
Forster, Alfred L., 2, Shaftesbury Place, Gateshead-on-Tyne ... (E) Nov. 1891
Forster, Edgar S., 2, Shaftesbury Terrace, Gateshead-on-Tyne ... (E) Jan. 1894
Forster, L. P., 23, Lovaine Crescent, Newcastle-on-Tyne ... ... (E) Nov. 1893

G.

Gaine, Roger L., 62, Harrison Street, Barrow-in-Furness ... ... (E) Dec. 1887
Gibson, Joseph H., c/o Messrs. Laird Bros., Birkenhead ... ... (E) April 1891
Gibson, Thomas, 162, Roker Avenue, Monkwearmouth, Sunderland (E) Nov. 1893
Golledge, W., 74, Rye Hill, Newcastle-on-Tyne ... ... (E) Nov. 1891

H.

Hamilton, Robert C., 2, Dene Crescent, Walker-on-Tyne, R.S.O.... (E) Dec. 1892
Hardy, Arthur, 5, Warwick Place, Newcastle-on-Tyne ... ... (E) Dec. 1892
Hewitt, John, 29, Holly Street, Jarrow-on-Tyne ... ... (S) Nov. 1890
Hinchliffe, Robert, 25, Hawthorn Street, Newcastle-on-Tyne ... (S) Nov. 1893
Hughes, Thomas C., 3, Summerhill Street, Newcastle-on-Tyne ... (E) Nov. 1893

J.

Jamieson, Jas. L. A., 20, Archbold Terrace, Newcastle-on-Tyne ... (E) Nov. 1893
Jannings, Frank, 6, South Terrace, Southwick, Sunderland ... (E) Mar. 1892
Jepson, Henry, 34, St. Mary's Place, Newcastle-on-Tyne ... ... (E) Nov. 1893
Johnson, Alington, 22, Camden Street, Southwick, Sunderland ... (E) Mar. 1892

K.

Keen, Harry Bernard, 6, Beauclere Terrace, Sunderland ... ... (S) Dec. 1889
Kennedy, Robert Sinclair, 6, Winifred Terrace, Sunderland ... (E) April 1893
Kerr, William, c/o Messrs. J. & G. Thompson & Co., Clydebank, Glasgow ... ... (S) Oct. 1891
Kitchin, Arnold, 1, York Place, East Hartlepool ... ... (E) Dec. 1892

L.

Lishman, John James, Jun., 16, Lovaine Place, North Shields ... (E) Dec. 1892

LECTED.

N.

Nichol, Bryce Gray, 35, Leazes Terrace, Newcastle-on-Tyne ... (E) Oct. 1891
Nicholson, James Henry, 30, Azalea Terrace South, Sunderland ... (E) Mar. 1892

P.

Pattison, Matthew Robson, 14, Lambton Street, Sunderland ... (E) Mar. 1891
Pearce, Standen L., 42, Milton Street, West Hartlepool ... ... (E) Dec. 1893
Pearson, James, 10, Beech Grove Road, Newcastle-on-Tyne ... (S) Nov. 1893
Pendred, L. St. L., 100, Westmoreland Road, Newcastle-on-Tyne (E) Mar. 1894
Pettit, Arthur Edward, Oatlands Park, Weybridge ... ... (E) Dec. 1892
Phillips, John Frederick, 33, Tower Wall, East Hartlepool ... (E) Oct. 1892

R.

Raincock, Walter, c/o Mrs. Ewart, 8, Washington Terrace, North Shields ... ... (N A) Dec. 1893
Rappoport, Fred. G., 6, North View, Heaton, Newcastle-on-Tyne... (E) Mar. 1894
Reid, John Robert, 25, Derwent Street, Sunderland ... ... (E) Nov. 1892
Rickaby, Augustine, Bloomfield Engine Works, Monkwearmouth, Sunderland... ... ... (E) Nov. 1885
Rishton, C. William, 17, Denmark Street, Gateshead-on-Tyne ... (E) Nov. 1893
Robinson, Charles O., Ingleside, North Shields ... ... (E) Dec. 1893

S.

Scott, Joseph, 49, Leazes Terrace, Newcastle-on-Tyne ... ... (E) Dec. 1891
Shilstone, Victor G., 14, Wentworth Place, Newcastle-on-Tyne ... (N A) Nov. 1891
Short, Thomas Smart, c/o Messrs. Short Brothers, Pallion, Sunderland... ... ... (S Oct. 1892
Simpson, Kenneth, 33, North View, Heaton, Newcastle-on-Tyne ... (S) Dec. 1893
Smith, William S., West Villa, The Green, Wallsend-on-Tyne ... (S) Dec. 1893
Spencer, Harry John, 3, Victoria Street, Newcastle-on-Tyne ... (E) Dec. 1892
Spours, William, 106, Addison Road, Heaton, Newcastle-on-Tyne (E) Nov. 1891
Squire, Charles E., Arnside House, Grosvenor Road, Newcastle-on-Tyne... ... ... (E E) Nov. 1893
Stanger, Thomas W., 38, Addison Road, Heaton, Newcastle-on-Tyne (E) Jan. 1892
Stephens, Henry C. J., 99, Dagnall Park, Selhurst, London, S.E.... (E) Oct. 1890
Stephenson, Robert, c/o Messrs. Robt. Stephenson & Co., Limited, Newcastle-on-Tyne ... ... (E) Mar. 1894
Summerson, Benjamin, Dene Crescent, Walker-on-Tyne, R.S.O. ... (E) Dec. 1892
Swan, George, Grove House, Gosforth, Newcastle-on-Tyne ... (E) Mar. 1894

T.

Taylor, M., c/o Messrs. Barclay, Curle, & Co., Shipbuilders, Whiteinch, near Glasgow ... ... (S) Feb. 1889
Thomas, Harold, 6, St. John's Road, Stockton-on-Tees ... ... (S) Dec. 1893
Thornley, Thomas W., 58, St. Luke's Terrace, Pallion, Sunderland (E) Mar. 1894
Tweddell, G. H., 26, Grove Street, Newcastle-on-Tyne ... ... (E E) May 1894

ELECTED.

W.

Wakeham, John F., 50, De Grey Street, Newcastle-on-Tyne ... (S) Mar. 1893
Walker, Gavin Knox, c/o Messrs. E. Scott, Mountain, & Co., The Close, Newcastle-on-Tyne ... ... (E) Mar. 1894
Warburton, John A., 15, Nelson Street, Sunderland ... ... (E) Mar. 1894
Watson, Arthur C., 7, Thornhill Terrace, Sunderland ... ... (S) Nov. 1891
Wawn, T. Noel, 6, Belle Vue, Sunderland ... . (E) Nov. 1893
Wedgewood, Josiah Clement ... ... (S) April 1891
Weightman, Thomas, 179, Portland Road, Newcastle-on-Tyne ... (S) Dec. 1892
Wight, Henry Dewair ... ... (E E) Oct. 1891
Wilkin, Ernest Vivian, 16, Chester Crescent, Newcastle-on-Tyne (E) Nov. 1892
Willcox, Reginald J. N., The Oaks West, Sunderland ... ... (E) Mar. 1892
Wilson, John R. S., Roseworth Tower, Gosforth, Newcastle-on-Tyne (E) Mar. 1894
Wood, John Scott, 6, Eslington Terrace, Newcastle-on-Tyne ... (S) Oct. 1891

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 4TH, 1887.

RE-REVISED AT THE CLOSING BUSINESS MEETINGS HELD ON MAY 9TH, 1888, MAY 13TH, 1889, AND MAY 11TH, 1891.

CONSTITUTION.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders." Name.

II.—The OBJECTS for which the Institution is established are :—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions. Objects.

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect. Honorary Members.

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be One Guinea per annum. Members.

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum. Associates.

Graduates.

VII.—GRADUATES may be persons under twenty-four years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Half-a-Guinea per annum.

Life Members and Associates.

VIII.—Any MEMBER may become a LIFE MEMBER by a single payment of Twenty Guineas, or any ASSOCIATE may become a LIFE ASSOCIATE by a single payment of Ten Guineas.

Officers.

IX.—The OFFICERS of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, nine Vice-Presidents, fifteen Councilmen, and an Honorary Treasurer.

Election of Officers. (See Bye-Law No. 11.)

X.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen shall be those who have served three years from their last election.

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents shall be eligible for re-election. The retiring Councilmen shall not be eligible for re-election to the same office until after an interval of one year, but shall be eligible for election to any other office.

The Honorary Treasurer shall be eligible for re-election annually, or for election to any other office.

Honorary Mem-

XI.—Honorary Members may attend all the General Meet-

tions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office.

XV.—The General Meetings of the Institution shall be held during the winter season of each year. General Meetings.

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

Revised at the Closing Business Meetings held on May 4th, 1887, *May 13th,* 1889, *and May 11th,* 1891.

MEMBERSHIP.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the Form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified. Proposals for Graduates must give the date of, and age, last birthday. Candidates for Admission.

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix. Graduates becoming Members.

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

3.—The balloting for membership shall be conducted in the following manner:—Each member shall be supplied by post with a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be Balloting for Members.

returned to the Secretary by post, or may be deposited in the ballot-box by the voter in person on entering a meeting at which an election is to take place. The ballot-box will be closed at ten minutes after the advertised time of meeting. The lists shall then be handed over to the Chairman, who shall appoint two Scrutineers to examine them, after which examination the Chairman shall inform the meeting of the result.

Candidates to receive Notice of Election.

4.—Notice of Election as a member shall be sent to the candidate within one week after his election, according to the Form D in the Appendix; but his name shall not be added to the list of Members, Associates, or Graduates of the Institution, until he shall have paid his first annual subscription.

Rejection of Candidates.

5.—In case of rejection of the candidate, no mention thereof shall be made in the minutes, nor shall any notice be given to the unsuccessful candidate.

Subscriptions payable in Advance.

6.—All subscriptions shall be payable in advance, and shall become due on the 1st of June each year. Any Member, Associate, or Graduate, wishing to retire from the Institution shall continue to be liable for his annual subscription until he shall have given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st of August in each year. Application for membership may be made at any time during a Session, and the subscription shall cover the membership up to the 1st of June following.

Receipt of Subscription.

7.—On payment of each subscription the Secretary shall forward to the member an official receipt.

Questions of Privilege.

8.—On question of privilege.—Any person who may be unknown in the meeting shall only be able to claim the privilege in question on proving his membership for the current Session.

Arrears of Subscriptions.

9.—Any member whose subscription is one year in arrear shall be reported to the Council, who shall direct application to be made for it, according to Form E in the Appendix; and in the event of its continuing in arrear until the end of that Session after such application, the Council shall have the power, after remonstrance by letter, according to the Form F in the Appendix, of declaring that the defaulter has ceased to be a member.

Power of Council to remove Name from List of members.

10.—The Council may refuse to continue to receive the subscriptions of any member who shall have wittingly acted in contravention of the Regulations of the Institution, or who shall,

in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form G in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

Election of Officers.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form H in the Appendix. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be one in excess of the number required in each section of the Council. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary, to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution.

Any voting paper returning either more or less than one President, six Vice-Presidents, one Honorary Treasurer, and fifteen Councilmen, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer,

to persons not so elected, shall count to them as Councilmen, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any Member be nominated on the list. For this purpose, the Secretary shall prepare, previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

Ballot to be declared at May Meeting.

12.—The result of the ballot for Officers shall be declared at the General Meeting, to be held in May, at which meeting general business shall be transacted. At the May General Meeting the newly-elected Officers, after being declared, shall enter into office; and this shall be the last meeting of the Session.

Power of Council to fill up Casual Vacancy.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another; and the Officers so appointed shall retire when the person whose place they fill would have retired. Vacancies not filled up during the year shall be filled at the General Election.

GENERAL MEETINGS.

General Meetings.

14.—The Annual General Meeting shall take place in October, and shall be held in Newcastle. The Ordinary Meetings shall take place in the second week in each following month during the Session, unless otherwise arranged by the Council, and at such hours and places as the Council may determine.

Notice of Meetings.

15.—Seven clear days' notice of every General Meeting, Ordin-

17.—Twenty Members shall constitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special Meeting. Quorum.

18.—The President shall be chairman at every meeting, and in his absence, one of the Past-Presidents or one of the Vice-Presidents; or in the absence of these, a Councilman shall take the chair; or if no Councilman be present and willing to take the chair, the meeting shall elect a Chairman. Chairman at Meetings.

19.—The decision of a General Meeting shall be ascertained by a show of hands; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by ballot. The manner of counting the votes shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote; otherwise he shall not vote. Decisions of General Meetings.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened. Questions of a Personal Nature in General Meetings.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed. Transactions of Business General Meetings.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be Dissolving a General Meeting.

dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

Adjourning a General Meeting.

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph.

Introduction of Friends.

24.—Each member shall have the privilege of introducing one friend to the General Meetings, whose name must be written in the Visitors' Book, together with that of the member introducing him; but if the introducing member be unable to attend the meeting, he may send the name of the visitor to the Secretary. During such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both, present request it.

COUNCIL MEETINGS.

Council Meetings.

25.—The Council shall meet before each General Meeting, or on other occasions when the President shall deem it necessary; being summoned in either case by circular, stating the time of meeting, and the business, so far as is known.

Convening Meeting for Expenditure of Funds.

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business.

Discussions of Personal Character.

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential.

Regulation of Proceedings.

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number.

Chairman and Quorum.

The President shall, *ex-officio*, be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair; or in the absence of these, one of the Councilmen shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum.

Sub-Committees.

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case,

and shall appoint a Chairman. These regulations shall not affect the Finance Committee.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution. Sub-Committees.

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best. Sub-Committees.

29.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote. Invitation to Strangers.

30.—The Secretary, who shall also act as Treasurer, shall be appointed by and act under the direction and control of the Council, and shall be paid such salary as the Council shall determine. He shall attend all meetings, Council and General, and shall take minutes of the proceedings, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. He shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council and the banking account shall be in the names indicated in connection with the Finance Committee. He shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department; and shall remain in office during the pleasure of the Council. He shall not vote on any resolution. Secretary and Treasurer's Duties.

31.—The following Sub-Committees shall be appointed annually at the first meeting of the Council in each Session:—

(1) A Finance Committee, to consist of seven persons, viz.: one Past-President or Vice-President, who shall be Chairman; five Finance Committee.

Councilmen, and the Honorary Treasurer of the Institution; three of whom shall form a quorum. The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque, signed by the Chairman of the Finance Committee (or in his absence, by the President or a Past-President), the Secretary and the Honorary Treasurer. (2) A Reading Committee, to consist of six members of Council. No member who has served on this Committee for three years in succession shall be eligible for re-election until after an interval of one year. (3) A Library Committee, in accordance with Library Bye-Laws, Nos. 1 and 3.

Payment of Accounts.

Reading and Library Committees.

TRANSACTIONS.

Papers to be submitted to Council.

32.—All papers shall be forwarded to the Secretary at least five clear weeks before the proposed date of reading. The Secretary shall submit them for approval to the Council, and on their general approval they shall be handed to the Reading Sub-Committee, three of whom at least, shall read the paper through. The Reading Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered.

Reading Committee.

Printing Transactions.

33.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have

turned to the Secretary within four days. A printed proof will also be sent to each speaker for further revision; this must be returned to the Secretary within three days, otherwise it will be deemed correct, and printed off after receiving verbal corrections.

Liberty to Print Explanatory Notes.

36.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications must be approved by the Reading Committee, and shall bear the date on which they shall have been received by the Secretary.

Institution not responsible for statements.

37.—The Institution shall not be held responsible for the statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

Copies of Transactions to be sent to members.

38.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. When a paper is prepared by two authors, fifteen copies shall be presented to each. Duplicate copies of parts of the Transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye-Law 41.

Transactions not supplied to members in Arrears.

39.—The Transactions shall not be supplied free to members whose subscriptions are more than one year in arrear.

Members not to receive Transactions till after First Payment.

40.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the Session to which his first subscription applies; but not until the subscription has been paid.

Transactions the Property of the Institution.

41.—The Transactions of the Institution shall be the exclusive property of the Institution, and shall be published only by the authority of the Council. Additional copies of papers required by authors for their private use can only be procured from the Secretary, at prices fixed by the Council from time to time, and these copies must contain the whole of the discussion following the papers, and be bound in the usual cover, with the addition of the following words:—"By permission of the Council," and "Excerpt Minutes of Proceedings." Duplicate volumes and copies of parts of the Transactions, if in print, can also be obtained from the Secretary, and shall be sold only by him, in such manner and at such prices as the Council shall have fixed.

Rule of Discussion.

42.—During a discussion upon any paper, no person shall be at liberty to speak more than once (except by way of explanation), nor for a longer period than ten minutes.

ACCOUNTS, &c.

Accounts.

43.—The Council shall present the yearly accounts (up to the 31st of May preceding) at the October General Meeting of each year, after they have been audited by a professional Accountant, appointed by the members at the General Meeting in May.

Trustees.

44.—The capital, stock, and funds of this Institution shall be vested in the names of three Trustees, to be elected from time to time as vacancies occur by the members of the Institution at a General Meeting called for that purpose. All mortgages and other securities shall be taken in the names of such Trustees; and on any new appointment the funds shall vest in the newly-appointed Trustee or Trustees jointly with the continuing or remaining Trustee or Trustees.

ALTERATIONS TO CONSTITUTION AND BYE-LAWS.

45.—Alteration in or addition to the Constitution and Bye-Laws may be made only by resolution of the members at the May General Meeting, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire; but in this case it shall be read at the May General Meeting in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the May General Meeting.

Vote by Proxy.

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form J in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye-Law 19.

THE LIBRARY AND READING ROOM BYE-LAWS.

1.—The Library and Reading Room shall be managed by a Committee, called the Library Committee, who shall have charge of all books, papers, specimens, etc., which may belong to the Institution. It shall consist of five members of the Institution, of whom at least two shall be members of Council. **Committee.**

2.—The books and other property of the Library shall be vested in the Trustees appointed by the Institution. **Property.**

3.—The Library Committee shall be appointed annually, at the first meeting of the Council in each Session. No member who has served on the Committee for three years in succession shall be eligible for re-election until after an interval of one year. The Chairman shall be elected by the Council. **Appointment of Committee.**

4.—The Secretary of the Institution shall be Librarian, and shall also act as Secretary to the Library Committee. Three members of the Committee shall form a quorum. **Librarian.**

5.—The Library Committee shall be responsible for the binding and purchasing of books, periodicals, papers, etc., and for the expending of all money voted by the Council for its use. It shall appoint an attendant who shall act as Assistant Librarian. It shall make Bye-Laws for the management of the Library, subject to the approval of the Council, and present an annual report to the first meeting of the Council held after the annual scrutiny of the books referred to in Bye-Law No. 13. **Duties of Committee.**

6.—Except when closed by special order of the Library Committee, or when the Council is sitting, the Library and Reading Room shall be open for consulting, borrowing, or returning books, every week day as follows:—On Monday, Tuesday, Wednesday, and Friday, from 10 a.m. to 12 noon, and from 1 to 9 p.m.; on Thursday, from 10 a.m. to 12 noon, and from 1 to 5 p.m.; on Saturday, from 10 a.m. to 1 p.m., and from 2·30 to 9 p.m. The Rooms will be closed on Christmas Day and the day following, New Year's Day and the day following, Good Friday, Monday and Tuesday in Easter week and Whit week, and the first Monday in August (being Bank Holiday); also at noon on Tuesday, Wednesday, Thursday and Friday in the Race week of June, and from the first to the second Saturday in March of each year, as mentioned in Bye-Law No. 13. **Hours of Opening and Closing, etc.**

7.—Books shall not be lent to any persons except Members, Associates, or Graduates of the Institution, but a person entitled to borrow a book may send a messenger with a signed order for it. **Lending of Books.**

Visitors.

8.—Each member shall be entitled to introduce a friend to the Reading Room, whose name shall be written in the Visitors' Book, together with that of the member introducing him.

Reference Books.

9.—The books marked with an asterisk in the Catalogue shall be kept only for consultation in the Library, and shall not be lent. Pending the preparation of a Catalogue, the Librarian shall be instructed by the Committee as to which books shall be withheld from circulation.

Unbound Books.

No periodicals, magazines, or pamphlets shall be issued for circulation until after they have been bound and added to the Lending Library.

Register of Books Lent, etc.

10.—The Librarian shall keep a register in which he himself or the attendant shall enter the titles of the books lent, the date of lending, the name of the borrower, and the date of the return of the book to the Library. The borrower of the book or the bearer of his order shall initial the entry of such borrowing, and the Librarian or the attendant shall initial the date of the return of the book.

Number Lent to each member.

11.—No person shall borrow or have in his possession at one time more than two volumes belonging to the Library.

Return of Books.

12.—No member shall retain a book longer than fourteen days, excluding the day of issue. He shall be responsible for the safe return of the book, and if it be damaged or lost he shall make good the cost of such damage or loss.

Yearly Inspection of Books.

13.—All books belonging to the Library shall be called in for inspection, and the lending out of books shall be suspended from the first to the second Saturday of March, inclusive, of each year, and members shall be required by an intimation inserted

APPENDIX TO BYE-LAWS.

FORM A. (BYE-LAW 1.)

Name (in full)
Profession or Occupation and where Employed
Address
being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned, propose and recommend that he shall become*
thereof. We know him to be†
and eligible for the proposed membership.

* A Member, Associate, or Graduate.

† A Principal, Manager, or Draughtsman, etc. See Articles V., VI., and VII of Constitution.

	FROM PERSONAL KNOWLEDGE.	SECTION OF MEMBERSHIP
Proposed by		
Supported by Three Members or Associates.		

Dated this day of

(*When a Graduate is proposed the age last birthday should be stated.*)

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being at present a of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of twenty-four years of age, and being desirous of becoming a of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge*, as a person eligible for the proposed Change of membership, because—

(*Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.*)

Signed _____ } Three [Members or Associates.]
_____
_____

Dated this day of 18

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

Member, Associate, or Graduate.	Occupation.	Address.	Nominated by.	Supported by Three Members or Associates.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

Sir,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have

FORM E. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to Bye-Law 6, and to remind you that the sum of £ of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,

Yours faithfully,

Secretary.

FORM F. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,

Yours faithfully,

Secretary.

FORM G. (BYE-LAW 10.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be.)

I am, Sir,

Yours faithfully,

Secretary.

FORM H. (BYE-LAW 11.)

BALLOTING LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lost.

_____ President for the current year (eligible for re-election.)*

_____
_____ } New Nominations, from whom to select ONE.
_____

VICE-PRESIDENTS.—NINE NAMES only to be returned (including the six who remain in office), or the vote will be lost.

_____
_____
_____ } Six Vice-Presidents remaining in office, whose seats are NOT vacant.
_____
_____

_____
_____ } Three Vice-Presidents retiring, eligible for re-election.
_____

_____
_____
_____ } New Nominations, from whom to select THREE names.
_____
_____

TREASURER.—ONE NAME only to be returned, or the vote will be lost.

_____ Treasurer for the current year, eligible for re-election.

_____
_____ } New Nominations, from whom to select ONE.
_____

COUNCILMEN.—FIFTEEN NAMES only to be returned, including the ten who remain in office.

_____
_____
_____

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Councilmen, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m., on 18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

FORM J. (BYE-LAW 45.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY.

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,....., being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr ..... who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the... .....day of ....., 18....., and at any adjournment thereof.

Signature... .....

Address .....

.....

.....*Secretary.*

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893-94.

PROCEEDINGS.

ROBERT THOMPSON, ESQ., PRESIDENT.

The tenth session of the Institution was inaugurated on the evening of October 24th, 1893, by a conversazione, concert, and ball, provided by the President, in the Assembly Rooms, Westgate Road, Newcastle-upon-Tyne, and was attended by a large assemblage of ladies and gentlemen. After the concert and before the dancing commenced, the President briefly addressed the guests from the platform in the large assembly room. He thanked them for their presence in such large numbers, and stated that he had repeated the function inaugurated by the late President (Mr. Wigham Richardson) two years ago, with a view of giving the ladies an interest in the Institution, and reconciling them to the absence of the gentlemen when attending the meetings of the Institution during the winter months. He had two pleasing duties to perform: the first being to declare the opening of the tenth session of the Institution, and the second to present the gold medals to the successful authors of papers read during the last session. It was only fair that he should state that some of the papers read last session had been contributed by members of the Council, but owing to their official capacity they were excluded by the rules from entering into the competition. He had pleasure in stating

that the gold medal for the best shipbuilding paper had been awarded to Mr. Stonard O. Kendall for his paper on "Strains of Tank Steamers," and that for the best engineering paper to Mr. J. Denholm Young for his paper "On a System of Mechanical Aid to the Investigation of Speed Curves."

Both of the above gentlemen being in the hall the medals were presented in due form.

On the motion of Mr. WIGHAM RICHARDSON a hearty vote of thanks was accorded by acclamation to the President for his kind hospitality.

The President was supported on the platform by the Past and Vice-Presidents and Members of the Council.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893–94.

PROCEEDINGS.

FIRST GENERAL MEETING OF THE SESSION, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, NOVEMBER 7TH, 1893.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Closing Business Meeting of the ninth session, held in Newcastle, on May 9th, 1893.

The ballot for new members having been taken, the President appointed Messrs. E. W. De Rusett and J. C. Stirzaker to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Alder, Sydney, Consulting Engineer and Naval Architect, Edinbro' Buildings, South Shields.

Bagnall, T. W., Forge Manager, The Groves, Winlaton-on-Tyne.

Basset, Walter Bassett, Engineer, 110, Westminster Bridge Road, London, S.E.

Boyt, John T., Superintendent Engineer, 204, South 3rd Street, Philadelphia, Pa., U.S.A.

Broadbent, Frank, Electrical Engineer, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-on-Tyne.

Bushell, Chas. A., Naval Architect and Ship Surveyor, 1, Benton Terrace, Newcastle-on-Tyne.

Calvert, Geo. A., Superintendent Engineer, Wellington Villa, St. Luke's, Cork.

Carruthers, Frank, Superintendent Engineer, 13, Hartington Street, Sunderland.

Cohn, William M., Draughtsman, 2, Marine Terrace, North Shields.

Copplestone, Henry J., Ship Draughtsman, 68, Crown Street, Newcastle-on-Tyne.
Daniel, Alfred John, Ship Draughtsman, 46, Kingsley Terrace, Newcastle-on-Tyne.
Dietze, F. G., Superintendent Engineer, Hamburg South American Steam Ship Company, Hamburg.
Dixon, William, Engineer, 7, Bolingbroke Street, Heaton, Newcastle-on-Tyne.
Douglass, William, Engineer, Globe Iron Works, Winlaton-on-Tyne.
Gad, Oscar, Draughtsman, Deptford Yard, Deptford, Sunderland.
Manaira, Guiseppe, Engineer and Naval Architect, c/o Messrs. E. Cravers & Co., Foce, Genoa, Italy.
Nicholls, H. E., Draughtsman, 25, Churchill Street, Sunderland.
Prosser, James, Mechanical Draughtsman, 205, Albert Road, Jarrow-on-Tyne.
Rosser, W. D., Manager, Cardiff Pontoon Company, Mount Stuart Square, Cardiff.
Sharman, Geo. Dixon, Ship Draughtsman, Deptford Yard Sunderland.
Welton, J. J., Draughtsman, 12, Hendon Valley Road, Sunderland.
Winter, Thor., Engineer Skeppsdockan, Helsingfors, Finland.

MEMBERS (LATE GRADUATES).

Doxford, Albert Ernest, Engineer, 2, West Lawn, Sunderland.
Freeman, Alfred Isaac, Engineer, 2, Regent Terrace, Newcastle-on-Tyne.
Metcalf, Thos., Jun., Marine Surveyor, 18, John Street, Sunderland.
Ritson, S. M., Marine Engineer, 18, St. Bede's Terrace, Sunderland.
Rutherford, J. T., Marine Engineer, 42, Wharncliffe Street, Newcastle-on-Tyne.

ASSOCIATES.

Adam, John B., Shipowner, Osborne Terrace, Newcastle-on-Tyne.
Anderson, Daniel G., Manager, Burnaby Lodge, Ryton-on-Tyne.
Barr, John Smith, Agent, 5, Mosley Street, Newcastle-on-Tyne.
Brims, D. N., Contractor, 4, St. Nicholas' Buildings, Newcastle-on-Tyne.
Hardy, John, Jun., Iron Merchant, Brunswick Street, West Hartlepool.
Hurndall, Sidney E., Manager, Printing Court Chambers, Newcastle-on-Tyne.
Jenkins, Alfred, Secretary, Mercantile Dry Dock Co., Croft House, Croft Terrace, Jarrow-on-Tyne.
Muir, James, Marine Superintendent, 2, Dingle Lane, Liverpool.
Murray, Matthew, Secretary to Messrs. Wallsend Slipway Co., The Green,

Hughes, Thomas C., Apprentice Engineer, 3, Summerhill Street, Newcastle-on-Tyne.

Jamieson, Jas. L. A., Apprentice M. E., 32, Lovaine Crescent, Newcastle-on-Tyne.

Pearson, James, Apprentice Ship Draughtsman, 10, Beech Grove Road, Newcastle-on-Tyne.

Rishton, C. William, Apprentice Engineer, 10, Cambridge Street, Newcastle-on-Tyne.

Squire, Charles E., Apprentice Electrical Engineer, Arnside House, Grosvenor Road, Newcastle-on-Tyne.

White, W. H., Draughtsman, The Terrace, East Boldon.

The SECRETARY submitted the ninth annual Report of the Council, and Financial Statement.

The PRESIDENT delivered a short address.

Mr. W. HÖK read a paper "On a Method of Comparing Steamship Performances and of Estimating Powers and Speeds of Ships."

COUNCIL REPORT.

(Ninth Session.)

The Council, in presenting its ninth annual report, has pleasure in stating that the finances of the Institution are in a satisfactory condition.

During the session the following papers of practical utility were read and discussed, viz. :—

"The Combustion of Coal and Prevention of Smoke." By Mr. J. R. Fothergill.

"A System of Mechanical Aid to the Investigation of Speed Curves." By Mr. J. Denholm Young.

"Marine Boiler Furnaces." By Mr. D. B. Morison.

"Apparatus for Determining the Amount of Water Suspended in Steam." By Mr. W. R. Cummins.

"Ship's Electrical Fittings for Lighting, Signalling, etc." By. Mr. L. Newitt.

"Types and Proportions of Mercantile Steamers in relation to Cost, Carrying-Capacity, and Speed." By Messrs. J. G. Jordan and R. Marlborough.

"Strains of Tank Steamers." By Mr. S. O. Kendall.

The gold medals for the eighth session were awarded as follows :— The Engineering Medal to Mr. J. Jennings Campbell for his paper on "Engines for Ships of War." The Shipbuilding Medal to Mr. M. C. James for his paper on "Tonnage Measurement."

In the Graduate section a still further improvement has taken place, and the meetings have been better attended. During the session the following papers were read and discussed, viz. :—

"A Modern Theory of the Rolling of Ships." By Mr. A. Young.

"Continuous Current Dynamos." By Mr. J. Brentnall Duckitt.

"Hydraulic Buffers." By Mr. W. H. Atherton.

"Floating Caissons." By Mr. J. King.

"Marine Boiler Construction." By Mr. E. F. Moroney.

Visits were also paid to the following works and places of interest :—

Redheugh Gas Works belonging to Messrs. The Newcastle-upon-Tyne and Gateshead Gas Company.

The Shipbuilding Yard of Messrs. W. Doxford & Sons, Sunderland, and the Turret-ship built by them.

Mr. F. Caw's Experimental Tank, Sunderland.

Messrs. The North-Eastern Railway Company's Locomotive Works, Gateshead-on-Tyne.

Messrs. John Abbot & Co.'s Works, Gateshead-on-Tyne.

The Shipbuilding Yard of Messrs. J. L. Thompson & Sons, Sunderland.

The prizes for the best papers read in this section during the eighth session were awarded as follows :—First award to Mr. J. King for his paper on "Some Notes on the Propulsion of Paddle Steamers." The second award was divided between Messrs. E. Towers and R. L. Gaine, the former for his paper on "Hydraulics and Hydraulic Machinery," and the latter for his paper on "Steamship Trials."

During the past year the following additions have been made to the list of members, viz. :—67 Members, 7 Associates, and 35 Graduates ; and 18 Graduates have been raised to the rank of Members.

The Institution regrets having to record the loss by death of the following :—Members.—Messrs. C. Ahlbom, William S. Cumming, J. Eltringham, J. C. R. Gemmell, and J. Livinstone. Associates.—Messrs. John Holmes and John Varley. Graduates.—Messrs. Alfred E. Hume, John R. Taylor, and William Boyd, Jun.

It has also lost from resignations and other causes—43 Members, 10 Associates, and 12 Graduates.

The total number of Members of all classes now enrolled on the books of the Institution is 892 as follows :—

Honorary Members	... ...	3
Life "	... ...	5
Ordinary "	... ...	677

The Council has arranged that photographic portraits of the Past-Presidents of the Institution be obtained and hung in the Institution's rooms. The contract for these portraits has been placed in the hands of Mr. James Bacon, Photographer, Northumberland Street, Newcastle-upon-Tyne.

The Council regrets having to report that the sum of the subscriptions in arrears has greatly increased; and it is hoped that those members whose subscriptions for previous years are still unpaid will at once remit the amount due to the Secretary.

E SHEET.—FOR THE SESSION ENDING 31ST MAY, 1893.

£	s.	d.	£	s.	d.
			1,692	13	5
618	2	0			
230	0	0			
			388	2	0
			£2,080	15	5

Assets.

		£	s.	d.	£	s.	d.
Subscriptions in Arrear—							
Session 1890-91		3	3	0			
„ 1891-92		13	13	0			
„ 1892-93		74	11	0			
					91	7	0
Stock of Transactions, valued at					147	19	6
Office and Library Furniture, Safe, etc., as at 31st May, 1892 ...	£124 12 0						
Less Depreciation	12 9 0						
		112	3	0			
Additions this Session		9	11	11			
					121	14	11
Books in Library—							
As at 31st May, 1892 ...	£164 13 4						
Less Depreciation ...	16 9 4						
		148	4	0			
Additions this Session		17	2	1			
					165	6	1
Tyne Improvement Commissioners—Investment of the following Funds:—							
Gold Medals' Fund		274	0	0			
Graduates' Award Fund		215	15	0			
Payments by Life Members and Associates		115	5	0			
					605	0	0
Cash—At Bankers		938	15	2			
In hand		10	12	9			
					949	7	11
					£2,080	15	5

Audited and certified,
R. W. SISSON, F.C.A.,
CHARTERED ACCOUNTANT.

ENGINEERS AND SHIPBUILDERS.

FOR SESSION ENDING 31ST MAY, 1893.

Payments.

	£ s. d.	£ s. d.
By Transactions and Papers—		
Lithographing	205 7 0	
Printing and Binding	303 11 3	508 18 3
„ Stationery and Circulars	69 11 4	
„ Reporting	26 4 0	
„ Rents—		
Offices	65 4 0	
Lecture Rooms	7 4 0	
Telephone	8 0 0	
„ Rates, Gas, and Insurance	12 18 10	
„ Salaries—		
Secretary, Salary	220 0 0	
Do. Commission	56 7 9	
Office Boy	10 0 0	
Assistant Librarian	35 0 0	
„ Postages, Stamps, Post Cards, Parcels, etc.	103 7 3	
„ Secretary's Expenses and Allowances to Hall Keepers ...	19 15 7	
„ Office Expenses, Coals, Cleaning, etc.	13 16 0	
„ Expenses of Graduates' Meetings and Hire of Lantern ...	2 13 8	
„ Rent for Measured Mile Posts	3 3 0	
„ Auditor's Fee	3 3 0	656 8 5
„ John Brown & Co., Ltd.—		
Balance from Sheffield Excursion voted to their Workmen's Sick Fund		6 4 0
„ Library Fund—		
Furniture	9 11 11	
New Books	8 4 1	
Bookbinding	8 18 0	26 14 0
„ Chair of Engineering and Naval Architecture Fund—		
One Year's donation towards Salary of Professor ...		230 0 0
„ Gold Medals' Fund (Two Medals Awarded)	9 10 0	
„ Graduates' Award Fund—Amounts Awarded for Papers...	7 12 6	17 2 6
„ Balance—		
At Bankers...	938 15 2	
In hand	10 12 9	949 7 11
		£2,394 15 1

E SHEET.—FOR THE SESSION ENDING 31ST MAY, 1893.

£	s.	d.	£	s.	d.
			1,692	13	5
618	2	0			
230	0	0			
			388	2	0
			£2,080	15	5

Assets.

		£ s. d.	£ s. d.
Subscriptions in Arrear—			
Session 1890-91		3 3 0	
„ 1891-92		13 13 0	
„ 1892-93		74 11 0	
			91 7 0
Stock of Transactions, valued at			147 19 6
Office and Library Furniture, Safe, etc., as at 31st May, 1892 ...	£124 12 0		
Less Depreciation	12 9 0		
		112 3 0	
Additions this Session		9 11 11	
			121 14 11
Books in Library—			
As at 31st May, 1892 ...	£164 13 4		
Less Depreciation ...	16 9 4		
		148 4 0	
Additions this Session		17 2 1	
			165 6 1
Tyne Improvement Commissioners—Investment of the following Funds:—			
Gold Medals' Fund		274 0 0	
Graduates' Award Fund		215 15 0	
Payments by Life Members and Associates		115 5 0	
			605 0 0
Cash—At Bankers		938 15 2	
In hand		10 12 9	
			949 7 11
			£2,080 15 5

Audited and certified,
R. W. SISSON, F.C.A.,
CHARTERED ACCOUNTANT.

LIST OF SUBSCRIPTIONS

RECEIVED TOWARDS THE SALARY OF THE PROFESSOR OF ENGINEERING AND NAVAL ARCHITECTURE IN THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-ON-TYNE. FROM AUGUST, 1892, TO AUGUST, 1893.

	£	s.	d.
Sir William Gray, West Hartlepool	30	0	0
Messrs. Wigham Richardson & Co., Walker-on-Tyne ...	30	0	0
„ John Readhead & Sons, South Shields	25	0	0
„ C. S. Swan & Hunter, Wallsend-on-Tyne ...	25	0	0
„ Bartram, Haswell & Co., Sunderland (2 years' subscription)	20	0	0
„ George Clark, Limited, Sunderland	20	0	0
John Dickinson, Esq., Sunderland...	20	0	0
Messrs. W. Doxford & Sons, Sunderland	20	0	0
James Laing, Esq., Sunderland	20	0	0
Charles Mitchell, Esq., Newcastle-on-Tyne	20	0	0
Messrs. N. E. Marine Engineering Co., Wallsend-on-Tyne	20	0	0
„ Thos. Richardson & Sons, Hartlepool	20	0	0
„ J. L. Thompson & Sons, Sunderland	20	0	0
„ The Wallsend Slipway Co., Wallsend-on-Tyne ...	20	0	0
„ The Sunderland Shipbuilding Co., Sunderland ...	15	0	0
Arthur Coote, Esq., Newcastle-on-Tyne	10	0	0
Messrs. J. Eltringham & Co., South Shields	10	0	0
„ John Spencer & Sons, Newburn-on-Tyne ...	10	0	0
„ J. Blumer & Co., Sunderland (donation)... ...	5	0	0
John Gravell, Esq., Newcastle-on-Tyne	5	0	0
Messrs. J. P. Rennoldson & Co., South Shields	5	0	0
„ Ropner & Sons, Stockton-on-Tees (donation) ...	5	0	0
„ Smith's Dock Co., North Shields	5	0	0
„ Westgarth, English & Co., Middlesbrough ...	5	0	0
„ Baird & Barnsley, North Shields	3	3	0
G. E. Macarthy, Esq., Newcastle-on-Tyne	2	2	0
Messrs. J. Priestman & Co., Sunderland	2	2	0
G. W. Sivewright, Esq., Hartlepool	2	2	0
	£394	9	0

IEET.—FOR THE SESSION ENDING 31ST MAY, 1893.

s. d.	£ s. d.
	1,692 13 5
618 2 0	
230 0 0	388 2 0
	£2,080 15 5

Assets.

	£ s. d.	£ s. d.
Subscriptions in Arrear—		
Session 1890–91	3 3 0	
" 1891–92	13 13 0	
" 1892–93	74 11 0	91 7 0
		147 19 6
Stock of Transactions, valued at		
Office and Library Furniture, Safe, etc., as at 31st May, 1892 ...	£124 12 0	
Less Depreciation	12 9 0	112 3 0
Additions this Session		9 11 11
		121 14 11
Books in Library—		
As at 31st May, 1892	£164 13 4	
Less Depreciation	16 9 4	148 4 0
Additions this Session		17 2 1
		165 6 1
Tyne Improvement Commissioners—Investment of the following Funds:—		
Gold Medals' Fund	274 0 0	
Graduates' Award Fund	215 15 0	
Payments by Life Members and Associates	115 5 0	605 0 0
Cash—At Bankers	938 15 2	
In hand	10 12 9	949 7 11
		£2,080 15 5

Audited and certified,
R. W. SISSON, F.C.A.,
CHARTERED ACCOUNTANT.

BALANCE SHEET.

Mr. J. C. STIRZAKER moved the adoption of the report and financial statement.

Mr. W. DALRYMPLE, in seconding, asked if the balance at the bankers was in the shape of a current account or invested as a deposit account?

The PRESIDENT said the Finance Committee were making arrangements for its investment.

The reports were adopted *nem. con.*

OPENING REMARKS BY THE PRESIDENT.

The PRESIDENT said, in formally opening the first business meeting of the session, it was not his intention to occupy their time with an inaugural address, but simply to make a few general remarks in reference to the work of the last and for the present session, and to express a few thoughts which might be useful in the future.

In the first place he must most heartily thank the Past-Presidents, Vice-Presidents, Council, and members, for so cordially accepting the invitation to the conversazione which he had the pleasure to give on the 24th ult., as a commencement to the proceedings of the present session. He also wished to specially thank their Secretary (Mr. John Duckitt) for his kind and assiduous attention, and those gentlemen who so pleasantly acted as stewards; also those who were present by invitation, and although not members of their Institution, were deeply interested in their proceedings, and to those who could not attend but sent kindly letters of

He felt all the more certain of this when they considered that through the influence of Mr. John Gravell, Prof. Weighton, and himself, as their President, they would be enabled by the generosity of a large number of firms in this and other districts, 27 in all, to shortly present to the College from this Institution an experimental quadruple engine, with boiler complete. The total estimated cost of these was about £3,000, so that coupled with the machines already presented to the College by its supporters, the engineering department was in a very good position, and they only required an experimental tank to make this and the shipbuilding requirements fully complete. He trusted that at an early date a future President might be in a position to announce that a tank had been added to the advantages offered to students by the College.

If funds could be obtained from those possessing them, and accruing from the Local Taxation Customs and Excise Act, for the establishing of lectures at the various centres of engineering and shipbuilding on the North-East Coast, the benefits of the College would be widely diffused and the interests of the district considerably furthered.

The report of the Council of the past session was of a satisfactory character. The papers read were of great practical value and the discussions showed that a considerable number of members had a thorough grasp of the questions raised, and possessed good debating powers. He might here take the liberty of expressing his pleasure at the two very successful meetings held at Hartlepool, and was glad to preside over such numerous gatherings.

The gold medals were awarded to Mr. S. O. Kendall for his paper on "Strains of Tank Steamers," and to Mr. J. Denholm Young for his paper "On a System of Mechanical Aid to the Investigation of Speed Curves," and were presented at the conversazione.

The present session also promised to be of an interesting character, so far as the reading of papers was concerned. He feared that the engineers were rather backward. He hoped that this was not because their President was a shipbuilder. He might say that personally this did not apply, as the only regret he sometimes felt was that he had not been made an engineer or a doctor.

He was pleased to note the continued improvement in the Graduate section. Their meetings had all been well attended, so much so that at present the Council had deputed Prof. Weighton and Mr. R. L. Gaine (the President of the Graduate section) to endeavour to induce the College authorities to extend their kindness to them by allowing the meetings to take place in that room. He trusted the authorities would agree to it. He

had attended several meetings of the Graduate section, and had generally admired their business tact, the high character of the papers, and the free manner in which the members joined in the discussions. He hoped the Council would see their way to have some of the papers read in that section printed and added to the *Transactions* of the Institution.

Though they had to regret the loss by death of several of their members, still they were on the upward grade in both sections, and the increase that night was a very material one.

He still looked forward to papers of practical value being contributed by some of their shipowning members and their superintendents. They might assist them in many ways by giving them the results of actual work done. In these times of severe depression and keen competition it must be of the utmost importance to all parties to have the opinion of practical men as to the value of the various forms and types of vessels. They were in a position to throw much light on the question of the paying value of fulness of model, when compared with higher speeds and finer vessels, carrying less deadweight. These were points of great commercial value, and any freely expressed opinion by those having intimate knowledge of the matter would receive full consideration.

There was a resolution on their minutes, moved by Mr. Sivewright, and passed by the Council, as follows:—"That any member may by communication addressed to the Secretary petition the Council to lay before a general meeting of the Institution the contents of any letter which shall in a short, concise, and clear manner draw the attention of the Institution to public matters of importance in connection with legislation proposed by any governing body in reference to the construction of ships, machinery, or working of the same, so that members might, by their scientific and practical knowledge, demonstrate the soundness or otherwise of the pro-

Then they had the grouping together or consolidation of the various Acts of Parliament under the Merchant Shipping Laws. Take the Tonnage Laws as now in force. They might ask that since all water ballast tanks in the main body of the vessel were allowed off tonnage, why no reduction was made off that portion of fore and after-peaks built and used exclusively for water ballast? Further, store rooms for provisions and navigation of vessel were deducted, but none for the space occupied by fresh water tanks for use of the crew, or that taken up by chains in locker. Cables were one of the necessities for the safe navigation of the vessel.

Questions of construction of framework of hulls—whether Z, channel, or bulb iron sections should be used instead of angles; boats—whether of steel or wood; compasses; steering gears; and other equally important items—would tend to start valuable discussions, and be of great practical utility.

Engineering questions were rife with importance. Whether plain or corrugated furnaces were best for the purpose intended? Whether reduced sizes of cylinders, and increased boiler power and longer stroke, were more economical than the sizes at present in general use? Whether a triple engine required a governor or not? What was the proportion of surface required for thrust bearing? Quadruple expansion engines, whether they were really economical at 180 or 200 lbs. pressure, if not, then what was the pressure which would result in a decided economy?

He simply threw out these suggestions to show that there was ample room for useful papers, and what could still be done to add to the success of the Institution.

The Sub-Committee of Lloyd's, while not having effected, or attempted to effect, any very radical changes in the rules, had been instrumental in assisting to bring about a more uniform practice in the carrying out of the rules. Some of these changes were the fixing of the sizes of anchor cranes, boats' davits, etc., making them to more nearly conform to the practice adopted by the largest builders in the kingdom. He regretted that although this committee had only been in existence a very short time they had lost four of the members by death, viz.:—R. Sennet, H. H. Laird, A. D. Bryce Douglas, and Dr. A. C. Kirk.

His observations of the general conduct of the business in committee were that the innovation was a step in the right direction, but its utility could be considerably increased if the drawing office staff of Lloyd's were augmented. It was impossible for the staff at present employed to keep pace with the continual suggestions and improvements being put forward

by shipbuilders and engineers. He thought, considering the large reserve funds accumulated by Lloyd's Registry, this addition could be easily attained, and would add greatly to its usefulness. At present the society had in Mr. Martell an exceptionally able man, and one of varied and extensive experience. Was it right that so much responsibility should be so centred? He took it that it was unfair to Mr. Martell, to the society, and to the shipowning community, who subscribed so largely to the funds.

The PRESIDENT, continuing, said he was tempted to say something about trade prospects. The outlook was so gloomy that the only ray of hope seemed to be this, that things could not be much worse. Any change therefore must be of an upward tendency and for the better, both for capital and labour. Regarding the latter it seemed to have been forgotten that the so-called capitalists of to-day were the working men of a hundred years ago or less. What was wanting was that emulation of labour which used to exist, but which he was afraid seemed of a waning nature to-day. With better education they should have a higher moral standard, the cultivation of sober habits and thriftiness, truthful and direct dealing with each other on both sides. There ought to be a feeling that the two must go together, because so soon as they became antagonistic the particular trade they were interested in must suffer, and thus entail loss to both parties. The general tendency was to drift into arrangements as a matter of immediate convenience, rather than to work on definite principles. In the end this course was sure to lead to disagreement and inevitable collision. He hoped the future in respect to the relations of capital and labour would be that they would become more closely allied, leaving capitalists free to give their particular branch of business the full scope of their energy and ingenuity.

reception, and, as a member of Council, he felt that the opportunity thus afforded for social intercourse between the members was a potent factor in riveting together the various sections and making firmer the bonds that went towards the assurance of a thriving and successful institution. For past services, and his address that evening, he moved a hearty vote of thanks to their worthy President.

Mr. E. W. De Rusett had much pleasure in seconding so desirable a proposition. He thought it was an omission, at the close of the last session, that while they thanked the Council, the President was left out altogether. He had only had the pleasure of knowing Mr. Thompson (the President) for a short time, but had during that period been much struck with the genial and hearty way in which he had conducted their gatherings, and thought it should be a pleasure, as well as a duty, for more of the members to attend and support him at the meetings. Besides, larger gatherings would extend the usefulness of the Institution, the *Transactions* of which, he had no hesitation in saying, were second to none.

The motion was adopted by acclamation.

The President thanked the meeting for the vote of thanks so heartily given. He could only say this, that his heart was in the work, and anything he could do to further the interests of the Institution, he was at all times ready and willing to accord. He was very pleased indeed, with the social evening at the commencement of the session, and thought such gatherings would tend to improve their business meetings, as it made the members better acquainted. It was a selfish world they lived in, and it was something to get away for a little from the turmoil and worry of business, to meet each other in a spirit of good fellowship and enjoy a happy evening together.

Mr. Hök read the first paper of the session "On a Method of Comparing Steamship Performances and of Estimating Powers and Speeds of Ships."

ON A METHOD OF COMPARING STEAMSHIP PERFORMANCES AND OF ESTIMATING POWERS AND SPEEDS OF SHIPS.

By W. HÖK, M.I.N.A., Member of Council.

[Read before the Institution, in Newcastle-upon-Tyne, on Tuesday, November 7th, 1893.]

Introduction.

This investigation is undertaken with the object in view of finding some method by which the powers and speeds of steam vessels may be estimated rapidly and with sufficient accuracy, and by which also the performances of such vessels may be compared, and their success or non-success in regard to expenditure of power ascertained.

Such a method can only consist of experimental data bound together in accordance with established scientific principles.

In hydrodynamics the only established principle is the law of comparison.

Thus the question arises—With experimental data and the law of comparison as our only material, how should the problem be attacked to yield a satisfactory return?

This question is best answered by asking another—What elements of form and size affect chiefly the resistance of ships at given speeds?

In considering this question, let us—at all events for the moment—disregard form, and try to settle in a satisfactory way which is the element of size by which the power at given speed seems mostly to depend—Length, breadth, draught, midship area, wet surface, or displacement.

It is now generally accepted that breadth, draught, and midship area play subordinate parts as regards their influence on the power compared to either length, wet surface, or displacement. So let us reject the former group without further comment.

The elements of size composing the latter group, on the other hand, are important factors in determining the resistance; and it is undoubtedly a delicate matter to decide which of these to retain in preference to the others.

But determine first of all the relative importance of wet surface and displacement.

It seems to the writer that at low speeds the surface plays a more prominent part than the displacement, and that at high speeds or, more correctly, at speeds where the wave-making element predominates, first place must be given to the displacement. The tendency of our time being towards higher and higher speeds, and coupling this to the circumstance that the displacement possesses a certain commercial value, it appears the correct thing to retain the displacement in preference to the surface.

The elements of size remaining for final consideration are length and displacement. Of these the displacement is undoubtedly the more important.

Thus, if we fix on the displacement as the most important factor and make it our basis of comparison in determining the resistance, we can bring ships for which we have experimental data into direct comparison by making them of equal displacement. But all these ships will probably be of unequal lengths, which circumstance defeats the object in view, namely, the comparison between ship and ship, on account of the influence of length on resistance.

On the other hand, if we make all ships of equal length they will probably all have different displacements, and this again is detrimental to a comparison.

We have, therefore, to choose between two contingencies—either to make all ships of equal displacement and then compare only those of approximately equal lengths, or make all ships of equal length and compare only those having approximately equal displacements.

And the writer has a preference for the latter, for the only reason that a small difference in displacement seems to affect the resistance less than

for which we possess trial data to a standard length, and then compare the powers required to propel a unit of displacement of these models of equal length at equal speeds.

It is to enable us to do this in accordance with established scientific principles that we require the aid of the law of comparison.

It was suggested by Mr. Purvis in 1880 that all ships should be reduced to 100 feet in length; and this length lending itself admirably to simplifying the actual work in estimating powers and speeds is here adopted.

Let us now see how the reduction of vessels to 100 feet models affects their dimensions, powers, and speeds. Adopting the following notations:—

	Actual Ship.	100 Feet Model.
Length	L ...	L_m = 100 ft.
Displacement	D ...	D_m.
Wet surface	S ...	S_m.
Surface friction horse-power ...	F ...	F_m.
Wave-making horse-power	W ...	W_m.
Indicated horse-power	I ...	I_m.
Propulsive coefficient	ρ ...	ρ_m.
Speed	V ...	V_m.

Ratio of linear dimensions of ship and 100 feet model ... $= l = \frac{L}{100}$.

Indicated horse-power per 100 square feet of wet surface for 100 feet model ... ... $= p_s$.

Indicated horse-power per ton of displacement for 100 feet model ... ... $= p_D$.

$$l\sqrt{l}\,\frac{S}{100} = U.$$

$$\frac{l}{D} \times \frac{S}{100} = \tau.$$

And surface friction correction ... ... $= q$.

We have $\rho \times I = W + F$ . . . . . (1),

And, similarly, $\rho_m \times I_m = W_m + F_m$ . . . . . (2).

Now, $W_m = \frac{W}{l^{3\cdot5}} = \frac{\rho I}{l^{3\cdot5}} - \frac{F}{l^{3\cdot5}}$ . . . (3) from (1).

And thus from (2) and (3).

$$\rho_m I_m = \frac{\rho I}{l^{3\cdot5}} - \left(\frac{F}{l^{3\cdot5}} - F_m\right),$$

and on account of $\frac{S_m}{100}$ being $= \frac{S}{100 l^2}$,

$$\frac{I_m}{\left(\frac{S_m}{100}\right)} = \frac{\rho}{\rho_m} \times \frac{I}{l\sqrt{l}\,\frac{S}{100}} - \frac{1}{\rho_m}\left(\frac{F}{l\sqrt{l}\,\frac{S}{100}} - \frac{F_m}{\left(\frac{S_m}{100}\right)}\right) \quad . \quad (4).$$

$$= \frac{\rho}{\rho_m} \times \frac{I}{U} - q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5).$$

At this stage we make the reasonable assumption that the propulsive coefficients of the actual ship and the 100 feet model are equal at corresponding speeds, and

Indicated horse-power per 100 square feet of wet surface for 100 feet model =

$$p_s = \frac{I_m}{\left(\frac{S_m}{100}\right)} = \frac{I}{U} - q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6).$$

q is the surface friction correction and denotes the amount by which the term $\frac{I}{U}$ has to be corrected in order to express the indicated horse-power *per* 100 *square feet of wet surface* for 100 feet model on account of the surface friction resistance varying with the actual length of surface and as the 1·825th instead of the second power of the speed. This correction (q) has been deduced from the experimental data published by Mr. R. E. Froude in the *Transactions of the Institution of Naval Architects* for 1888; and the process of deduction of q and the construction and application of Diagram 1 (Plate I.) containing curves of q for a wide range of speed and for lengths of vessel varying from 40 to 600 feet is described in Appendix A, page 36.

But we require the indicated horse-power *per ton of displacement* for 100 feet model.

$$\frac{I_m}{\left(\frac{S_m}{100}\right)} = p_s \text{ and thus } I_m = p_s \times \left(\frac{S_m}{100}\right).$$

Therefore $\frac{I_m}{\left(\frac{D}{l^3}\right)}$ = indicated horse-power per ton of displacement for

$$\left.\begin{array}{l}\text{Deduct } q \text{ from } \frac{I}{U} \text{ if } L < 100 \text{ feet} \\ \text{Add } q \text{ to } \frac{I}{U} \text{ if } L > 100 \text{ feet}\end{array}\right\} \text{and we have } p_s.$$

Find now $\tau = \frac{l}{D} \times \frac{S}{100}$, multiply it by p_s, and we have finally $p_D =$ indicated horse-power per ton of displacement for 100 feet model at speed V_m.

The Wet Surface.

The only element of size required in this method, which is not always known and which occupies some time in computing, is the wet surface. This fact is, no doubt, the principal reason why methods based on the expenditure of power per unit of surface fail to become popular. But it is evident that for the purpose we need the surface in this method, *i.e.*, for effecting a correction, which in itself is of very small magnitude, a very approximate surface is all that is required.

The approximate surface used by the writer for years is a simplified form of the well-known surface invented by the late Dr. Kirk.

Let D be the displacement of ship,
L „ length,
B „ breadth,
d „ draught,
ω „ block coefficient of displacement,
S „ surface.

$$\text{Then } S = \frac{35 \times D}{d} + 2dL \quad \ldots \ldots \ldots \ldots (7).$$

$$= L(\omega B + 2d) \quad \ldots \ldots \ldots \ldots (8).$$

As will be seen, these expressions have the advantage of being composed of only the principal elements of size and form. For their absolute accuracy not much is claimed; they, however, compare very favourably with the surface obtained by Kirk's analysis and are much simpler to use. (For further information on this point see Appendix B, page 38.)

The principal elements of size are by the reduction of ships to 100 feet models affected in the following way :—

	Actual Ship.	100 Feet Model.
Breadth	B ...	$B_m = \frac{B}{l}$.
Draught	d ...	$d_m = \frac{d}{l}$.
Displacement	D ...	$D_m = \frac{D}{l^3}$.

The coefficients and all elements of form being unaffected by any change in absolute dimensions are the same in the 100 feet model as in the actual ship.

In the way described we convert all trial data for actual ships into speeds (V_m) and powers per ton of displacement (p_D) for 100 feet models. These data are then graphically recorded on Diagrams such as 2 to 7 (Plates II. to VII.), where the abscissæ represent V_m and the ordinates p_D, and are so grouped that ships of approximately equal displacements (D_m) are placed together.

The Diagrams and the Trial Data.

The diagrams here presented contain speed and power data for vessels the actual lengths of which range from 48 to 565 feet. Nearly all existing types are represented, including launches and yachts, torpedo boats, torpedo catchers, cruisers and battle ships, Atlantic liners and plain cargo steamers, ships driven by means of single, twin, and triple screws, paddle wheels and guide blade propellers. The data of these ships are mostly collected from the Transactions of learned societies; a few, however, the accuracy of which seemed beyond doubt, are taken from engineering journals of high standing. The writer is also indebted to Mr. Arthur Laing for allowing the use of data for some cargo steamers built at Deptford yard. The data on the diagrams, whether curves or spots, are marked by distinguishing numbers, and the corresponding size and form characteristics are given in Appendix C, page 39. No absolute dimensions are given however, the ships being all reduced to 100 feet models, but in order to heighten the interest, the names of those ships which are well-known in the engineering world and which have already been published in the Transactions of learned societies and public prints are added.

can therefore not compare ships, at least not ships having proportionately widely different machinery, unless we first apply a correction to their speed curves of such character as to practically annul the influence of size and speed of machinery.

Call i the power consumed in friction,

then at speed V the engine efficiency $= \epsilon = \frac{I - i}{I}$,

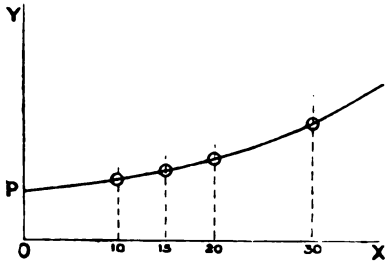
and " V_{max} " " $= \epsilon_{max} = \frac{I_{max} - i_{max}}{I_{max}}$.

Then by making an assumption, which we are indeed compelled to make on account of the present imperfect state of knowledge, that the screw efficiency is constant at all speeds for the same ship, we have that the propulsive coefficients at different speeds vary as the engine efficiencies; consequently, the ratio of the propulsive coefficients at speeds V and V_{max} $= \frac{\epsilon}{\epsilon_{max}}$ = coefficient of engine friction correction $= \mu$.

Supposing, then, that the propulsive coefficient is ρ_{max} at speed V_{max}, we obtain by multiplying the powers at the different speeds by the corresponding values of μ, a speed curve having a constant propulsive coefficient at all speeds (same coefficient as at maximum speed), *i.e.*, a speed curve which is proportional to the curve of hull resistance. We have consequently eliminated the varying influence of the engine friction and are now enabled to compare the hulls of ships having widely different size and speed of engines.

The chief difficulty in connection with this engine friction correction lies in determining it. In the first instance, we have to find the power spent in friction at the different speeds. Now, it is impossible to evaluate the dynamical friction without special appliances; it is probable, however, that this kind of friction has so small an influence on the engine friction correction, that it can for our purpose be assumed with sufficient accuracy, or that it may even be neglected.

The statical friction, on the other hand, must not be assumed. There is, besides, no need for resorting to an assumption in this case, as the statical friction is simple and inexpensive to determine in the following way:—Run the engine on trial, say 10, 15, 20, and 30 revolutions, take indicator cards,



plot the obtained mean pressures as ordinates to revolutions as abscissæ,

draw a curve through the spots, and produce it until it intersects the axis O Y. O P is then for all practical purposes the value of the statical friction of the engine. The further work entailed by finding the engine friction correction at the various speeds, and applying it to the speed curve, is so simple that no explanation is deemed necessary.

Curves A, B, and C, Diagram 8 (Plate VIII.), are a few curves of engine friction correction. They are the outcome of knowledge obtained from some of Mr. Laing's ships, for which the statical friction of the engines was determined some seven years ago in the manner described. Curve C was afterwards used in correcting those speed curves on Diagrams 2 to 7 (Plates II. to VII.), which are drawn on Diagrams 9, 10, and 11. (Plates IX., X., and XI.). Although it is not absolutely correct to use the same curve of correction for all ships, it was the only thing to do under the circumstances. It is, nevertheless, at once seen that notwithstanding the necessarily approximate nature of the engine friction correction, it has had a beneficial effect, for whereas, in Diagrams 2 to 7 the direction of the curves at low speeds is decidedly irregular, in Diagrams 9 and 10 greater regularity has ensued. The whole length of the corrected curves can now be used for estimating purposes, for at any point thereof the propulsive coefficient is equal to the propulsive coefficient at maximum speed.

Estimating Powers and Speeds.*

The corrected curves on Diagrams 9, 10, and 11 (Plates IX., X., and XI.) are used in estimating powers and speeds of ships. Let L, B, *d*, D, and V be the length, breadth, draught, displacement, and speed of a ship. What power (I) is now required?

Make ship into a 100 feet model—

$$\text{Find also surface} = S = \frac{35 \times D}{d} + 2dL,$$

$$\text{,, ,,} \quad U = l\sqrt{l}\,\frac{S}{100},$$

$$\text{,, ,,} \quad \tau = \frac{l}{D} \times \frac{S}{100}.$$

Now select among the 100 feet models (Appendix C) the one most similar, especially in regard to block coefficient of fineness (ω).

Take from Diagrams 9, 10, or 11 the power per ton of displacement for 100 feet model at speed V_m ($= p_D$).

Find $p_s = \frac{p_D}{\tau}$ = power per 100 square feet of wet surface for model.

Take from Diagram 1 the skin friction correction (q) for ship L feet long at speed V_m, and

Indicated horse-power for actual ship L feet long

$$= (p_s + q)\ U \text{ at speed } V.$$

Add q to p_s when $L < 100$ feet.

Deduct q from p_s ,, $L > 100$ feet.

If, on the other hand, the power is known and the speed required, the procedure is very similar. However, we have here a slight difficulty to contend with, being the evaluation of the skin friction correction q, owing to the nature of Diagram 1, Plate I. We have first to guess V_m, which is indeed the quantity we want to find; if the assumed V_m should happen to be widely different to the actual V_m, a second approximation may be necessary, but if the estimator has the slightest experience in his work such occurrences need be extremely rare.

For numerical examples, when speed is known and power required, and power known and speed required, see Appendix D.

NOTE.—On the supposition that when only a very rough idea of the power is wanted, the skin friction correction (q) is omitted, the approximate power can be rapidly estimated from the diagrams without any previous calculation of the wet surface by simply multiplying the ordinate p_D by $D \times \sqrt{l}$. This approximate power will always exceed the actual power in ships over 100 feet in length, and be less than the actual power in ships under 100 feet in length by the amount of the skin friction correction.

ANALYSIS OF TRIAL DATA AND COMPARISON OF STEAM-SHIP PERFORMANCES.

It is impossible within the compass of a paper to discuss minutely all these trials. Nor is it absolutely necessary. They form, however, an

interesting study; and although incomplete in many respects, they seem to throw light on a great many matters in connection with steamship propulsion, of which the following are the principal:—

1. *Truth of the Law of Comparison.*—That the law of comparison on which this method is based is a scientific truth is testified by numerous trials, notably by No. 32, which ship is 525 feet long, and No. 46, 190 feet long; by No. 24A, 565 feet long, and No. 21, 230 feet long; by No. 5, 108 feet long, and No. 19B, 312 feet long; by No. 77C, 88 feet long, and No. 79, 300 feet long; by No. 136A, 68 feet long, and No. 128, 325 feet long, and many others.

2. *Unsuitable Propellers, Foul Bottom, and generally Low Propulsive Coefficient.*—It is evident that one of the advantages of this method is the certainty with which it points out inferior performances. To show this the writer has added speed curves of ships noted for the inferior results they gave on trial. No. 77A represents H.M.S. "Iris" with her original propellers. The position of her curve singles her out at once as a bad result. No. 77, on the other hand, is the "Iris" with new propellers, and the altered position of her curve shows how much more satisfactory is now her performance.

No. 98A, H.M.S. "Medea," compared with her sister ship, the "Medusa" (No. 98), exhibits the retarding influence of a foul bottom.

H.M.S. "Greyhound" (No. 125B) and H.M.S. "Mutine" (No. 125C) show the effect of generally bad performances. The propulsive coefficient of the former is, according to the late Mr. Froude, ·422, and of the latter ·363 at maximum speed instead of ·500 and above which is now very common in modern steamers.

3. *Engine Friction.*—The presence of excessive engine friction discloses

In modern practice the frictional element has an important bearing on ship construction. It appears that one large engine equal to the collective power of several small ones consumes less power in friction. Hence it follows that the efficiency of ships is reduced by multiplying the number of main engines. This is noticeable at lower speeds in the "Paris" (No. 32), twin-screw, compared with the "Umbria" (No. 31B), single screw; and also in H.M.S. "Blenheim" (No. 110), driven on the tandem principle by four engines, compared with H.M.S. "Edgar" (No. 105) driven by only two. But that at maximum speeds the efficiency is so high in twin-screw ships must be accounted for by more efficient propellers.

4. *Influence of Draught of Water.*—A comparison between the expenditure of power in steamers of shallow and deep draught reveals at once the advantage of deep draught in propulsion. For instance, paddle steamers Nos. 4 and 6 and others of very shallow draught, compared to paddle steamers Nos. 28 and 44, require about 50 per cent. more power at equal speed. The influence of draught has recently been prominently brought forward in other places in connection with Atlantic liners; and these diagrams abound in proofs of its importance on the future of steamship propulsion, and the correctness of the views held by Prof. Biles and Dr. Elgar on this matter.

5. *Single Screw versus Twin-screws.*—This is perhaps the most interesting comparison of all, namely, the comparison of vessels driven by single and twin-screws. A glance at Diagrams 4, 5, 6, and 7 shows conclusively that, generally speaking, twin-screws are superior to the single screw. In corroboration of this we may specially point to the ships referred to by Mr. White in his paper before the Naval Architects in 1878, and which ships are plotted on Diagram 7, to the "Umbria" (No. 31B) and the "Paris" (No. 32), merchant steamer (No. 51), and Government cruiser (No. 60). Finally, all the more recent warships, Nos. 125, 129, 140, 105, 110, 135A, etc., corroborate this view; and although their superiority may be due to a combination of several causes, it can hardly be doubted that the twin-screw system adopted in them has a great deal to do with their general excellence.

6. *Triple Screws.*—For proving the efficiency of triple screws we have only the trial of the "Tripoli," published by Mr. Marshall in 1887. This ship does not merely show an excellent result with triple screws (No. 25) but lends itself admirably to comparing triple screws with twin-screws, and twin-screws with the single screw. No. 24 shows the ship running with only two screws. This performance is almost as good as the previous one. But if we compare No. 24 with No. 21, which latter is the

"Tripoli" being propelled by only one screw, there is a noticeable falling off in performance, which must be attributed to the single screw.

7. *Guide Blade Propellers.*—The only example (No. 1) we have of a ship driven by guide blade propellers shows high expenditure of power. It would be precipitate to attribute this to inefficiency of the propelling instrument; it is rather due to the extreme shallowness of the model.

8. *Paddle Wheels.*—Like guide blade propellers, paddle wheels appear less efficient than screws. However, their inefficiency is purely chimerical, and is due to the shallow draught and its accompanying increase of resistance. This is proved by the performances of paddle steamers Nos. 53, 28, and 44, which draw about the same water as numerous screw steamers. It therefore appears to the writer that, generally speaking, in similar models paddle wheels are about equal in efficiency to the single screw, but inferior to twin-screws, which latter view seems corroborated by cruiser "Vesuvius" (No. 15) and cruiser "Tripoli" (No. 24), when compared with paddle steamer No. 17.

9. *Influence of Fineness and Displacement on Powers and Speeds in Ships of Equal Length.*—We now come to the most important, and perhaps also the most instructive, comparison of all in connection with steamship propulsion, namely, the influence of fineness and displacement on power and speed. Here let us solely confine ourselves to the corrected Diagrams 9 and 10. A comparison of No. 122, a steamer ·76 in fineness; No. 92, ·74 in fineness; No. 50, ·65 in fineness; No. 85, ·61 in fineness; and No. 65, ·57 in fineness, discloses at once the intimate connection between fineness and expenditure of power. We can without undue extravagance drive No. 122, 5¾ knots; No. 92, 6½ knots; No. 50, 7½ knots; No. 85, 8 knots; and No. 65, 8¾ knots. If we to these couple the steam trials of

themselves to be easily driven almost double that speed, but actually take less power to drive at the economical speeds of the latter. This is indeed significant. It undoubtedly points out the form of ship which will have to be adopted when the shipowners demand higher speed in the future.

There are a great many more trials on Diagrams 9 and 10 than those referred to, showing most convincingly the superiority of broad and fine ships when compared to narrow and full ones, such as the "Edgar's" (No. 105), the "Blenheim's" (No. 110), and the "Royal Sovereign's" (No. 135A), and there are also numerous vessels showing the advantages of ever so little more fineness at the expense of increased breadth, such as for instance Atlantic liners, Nos. 27 and 36 over No. 26, liner No. 32 over cargo steamer No. 49A, and cruisers Nos. 80, 79, 80A, and 84B over others.

The curves on Diagrams 9, 10, and 11 (Plates IX., X., and XI.) seem also to give a faint indication of the fineness appropriate to speed; and the writer has consequently ventured to indicate in the following table the speed which should not be exceeded in ships of given fineness, and *vice versa* the fineness of model that should be allowed for given speed:—

Block Coefficients of Fineness.	Speed for 100 feet Model in Knots.
·8	5½
·7	7
·6	9
·5	12
·45	14
·4	17
·35	20
·3	24

We also learn from Diagrams 9 and 10 that ships of small displacements in proportion to length, such as torpedo boats, paddle steamers, etc., take somewhat more power per ton of displacement to drive than vessels of very large displacements when steaming at speeds not exceeding those appropriate to their fineness. This anomaly must principally be due to larger wet surface in proportion to displacement and to less draught in the former ships. As a corroboration, take a torpedo boat of 40 tons displacement. She requires $1{\cdot}5 \times 40 = 60$ horse-power at 11 knots, whereas a vessel of 250 tons requires only $1 \times 250 = 250$ indicated horse-power at the same speed. This is an important factor which should be well kept in mind when the necessity arises for fixing the most suitable dimensions and fineness of steamers with a view to all-round economy.

On Progress in Steamship Propulsion.

Although this paper has already run to an inordinate length, the writer cannot conclude without comparing, if ever so incompletely, the progress made in the Mercantile Marine with that in the Navy.

Progress in the Navy.—A special diagram is prepared (No. 12, Plate XII.) showing the progress in the Navy. The different trials fall into four groups, easily distinguishable, and marked A, B, C, and D.

Group A consists of single screw ships, such as No. 135, the "Sultan;" No. 137, the "Bellerophon;" No. 131, the "Hercules;" and others, built over twenty years ago.

Group B represents a few twin-screw ships, such as No. 127, the "Captain;" No. 134, the "Iron Duke;" No. 138, the "Alexandra;" No. 145, the "Nelson;" and No. 139, the "Vanguard," built at a somewhat later period. Compared with Group A they mark the progress made in the earlier ships by the adoption of twin-screws.

Group C are ships built some ten years later, or about ten years ago, such as No. 125, the "Edinburgh;" No. 129, the "Collingwood;" No. 130, the "Imperieuse;" and No. 140, the "Howe." They are all twin-screws, and show, all-round, a considerable advance on the earlier twin-screws in Group B.

Finally, we have Group D, consisting of the most recent additions to the Navy, such as No. 105, the "Edgar;" No. 110, the "Blenheim;" and No. 135A, the "Royal Sovereign." This group, compared with the others, indicates very distinctly the remarkable advance made during the last twenty years in the Navy. By comparing groups A and D, it is seen that the most modern ships require at the maximum speeds of the earlier ships only half their power, and that when developing the maximum powers

waste of power; but, judging from comparison with the other types, one is inclined to expect better performances from vessels of so exceedingly fine lines. Their fineness may, however, be more apparent than real, owing to the fine midship section and proportionately large prismatic coefficient.

The data for the Atlantic liners are very complete. They show most conclusively that in this type no tangible improvement has taken place (in regard to expenditure of power, of course) for a considerable period of time. Moreover, liners do not seem to have benefited by the introduction of twin-screws, for several of the single screw vessels are fully as efficient as any of the most modern twin-screws.

Similarly, in regard to cargo steamers, there is no indication of an improvement. But, on the other hand, we have here to record a steady and most palpable retrogression (which fortunately now has reached its limit), not, however, as regards actual expenditure of power at moderate speeds, but with regard to the speeds themselves. The speed of the cargo steamer has for years steadily declined (*i.e.*, in relation to size of ship). This is due—as is well known—to the high expenditure of power above moderate speeds of the form of vessel which the builders have on account of the rules governing ships' scantlings been driven to adopt. This form which, owing to a penalty being placed on breadth and practically none on fulness, more resembles a rectangular box than a ship, declines to be propelled with economy at speeds above five and a half to six knots (referring to 100 feet model, of course), as evidenced by several speed curves of modern cargo steamers on Diagram 9.

Conclusion.

We have finally to compare the best performances in the Navy with those in the Mercantile Marine. If we then direct our attention to the trials of the "Edgar" (No. 105), the "Blenheim" (No. 110), and the "Royal Sovereign" (No. 135A), *i.e.*, to ships representing the most recent additions to the Navy, we notice that their performances are unapproached by anything in the Mercantile Marine (as represented on these diagrams), both as regards speed capabilities and power expenditure. This important fact gives at once rise to the following speculations:—Would it be advantageous to make Atlantic liners after the model of the "Edgar," and cargo steamers after that of the "Royal Sovereign"? If so, what changes in the building rules would make it profitable, and what alterations to docks, harbours and rivers would make it possible? It is a series of problems which are recommended for the consideration of the members of this Institution.

And, in conclusion, how has it come to pass that such progress has taken place in the Navy, particularly in connection with the most recent ships? The only likely answer is: through experiments with models of ships and screws.

The Navy having now shown that their methods are productive of good results, would it not lead to something tangible in connection with the Mercantile Marine if, like the late Mr. William Denny, the private shipbuilders pursued a similar course?

APPENDIX A.

Skin Friction Correction.

The skin friction correction for ships of different lengths at different speeds, denoted by q (page 23) and put equal to

$$\frac{1}{\rho_m}\left[\frac{F}{l\sqrt{l}\,\frac{S}{100}} - \frac{F_m}{\left(\frac{S_m}{100}\right)}\right]$$

is obtained from Mr. R. E. Froude's paper before the Institution of Naval Architects, 1888.

As the writer cannot possibly here go over the ground covered by Mr. Froude, a knowledge of his work in connection with this matter is indispensable for understanding the following equation deduced from the said paper:—

Call f the skin friction resistance in pounds.

„ O a factor varying with length of ship. Using the same notations as in the body of this paper.

Therefore

$$\frac{F}{l\sqrt{l}\,\frac{S}{100}} = \frac{101{\cdot}33 \times 64 \times {\cdot}10552^{1{\cdot}825}}{3300} \times O \times V_m^{2{\cdot}825} = \frac{O \times V_m^{2{\cdot}825}}{30{\cdot}832},$$

and for L feet ship $\dfrac{F}{l\sqrt{l}\,\frac{S}{100}} = \dfrac{V_m^{2{\cdot}825}}{30{\cdot}832} \times O_L.$

Likewise for 100 feet model $\dfrac{F_m}{\left(\frac{S_m}{100}\right)} = \dfrac{V_m^{2{\cdot}825}}{30{\cdot}832} \times O_{100}.$

Thus $\dfrac{F}{l\sqrt{l}\,\frac{S}{100}} - \dfrac{F_m}{\left(\frac{S_{100}}{100}\right)} = \dfrac{V_m^{2{\cdot}825}}{30{\cdot}832}\left[O_L - O_{100}\right];$

and on the supposition that $\rho_m = \frac{1}{2}$ we finally obtain

$$q = \frac{V_m^{2{\cdot}825}}{15{\cdot}416}\left[O_L - O_{100}\right].$$

Now by using the values of O to be found in Mr. Froude's paper (page 313), calculate q for different speeds V_m of 100 feet model, and make a diagram, such as Diagram 1 (Plate I.), where q is the skin friction correction for various lengths of ships at different speeds V_m of 100 feet model.

Diagram 1, embraces the skin friction correction for all ships but those having exceptional speeds for their size. In special cases, therefore, the diagram may require to be extended, and this is easily done by means of the equation for q above.

The skin friction correction (q) is positive for $L < 100$ feet,
and negative for $L > 100$ feet.

Therefore, if vessels are being reduced in size, add skin friction correction to $\frac{I}{U}$ and p_s.

On the contrary, if vessels are increased in size, deduct skin friction correction q from $\frac{I}{U}$ and p_s.

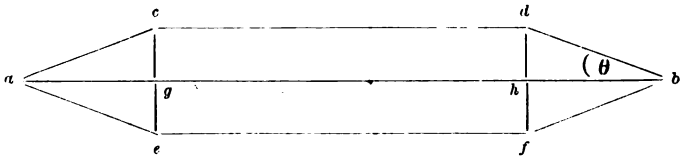
The former case includes vessels above 100 feet in length being reduced to 100 feet models, and 100 feet models made into vessels under 100 feet long. The latter case comprises vessels under 100 feet being enlarged to 100 feet models, and 100 feet models made into vessels over 100 feet long.

APPENDIX B.

The Wet Surface.

The wet surface given in the body of the paper (page 25) is a simplified form of the surface obtained by Kirk's analysis.

Let



be Kirk's block model.

By putting $bd = bh$ and, of course, $ac = ag$, the formula for the wet surface takes the form given on page 25.

The difference between Kirk's surface and this one, arising out of the above simplification, is extremely small, being equal to $2\,M \tan \frac{1}{2}\theta$ if M is the midship area and $\theta\,\frac{1}{2}$ angle of entrance. The extreme values of θ in ships of all classes being 5 degs. and 20 degs., the value of the difference between the two surfaces lies between $\frac{M}{10}$ and $\frac{M}{3}$, and is thus a very small percentage indeed of the total surface. Moreover, Kirk's surface exceeding in most cases the exact surface, and the above surface being always smaller, to the extent described, than Kirk's surface, it follows that the approximate surface used in this investigation more nearly represents the exact surface than Dr. Kirk's, as is also testified by the following table:—

	Exact Surface.	Surface by Formula (7).	Kirk's Surface.
1	19.348	20.705	20.847

APPENDIX C.

PRINCIPAL CHARACTERISTICS OF THE 100 FEET MODELS WHOSE SPEED CURVES AND SPEED SPOTS ARE DRAWN ON DIAGRAMS 2 TO 7 AND 9 TO 12 INCLUSIVE.

Number.	Type and Name.	Displacement. (D_m)	Block Coefficient of Displacement. (ω)	Breadth. (B_m)	Draught. (d_m)
1	Ernest (guide-blade propellers) ...	26·6	·536	15·00	1·15
2	Sunderland (torpedo boat) ...	32·6	·401	10·00	2·89
2A	Torpedo boat	34·1	—	10·00	—
3	Paddle steamer	34·2	·476	11·98	2·10
4	Paddle steamer	34·4	·565	10·67	2·00
5	Torpedo boat	36·6	—	—	—
6	Paddle steamer	37·5	·552	10·77	2·21
7A	Cushing (torpedo boat)	39·6	·383	10·28	3·51
8	Miranda (launch)	39·7	—	14·29	—
9	Torpedo boat	40·8	·440	11·67	2·78
10	Torpedo boat	41·9	·375	10·37	3·76
10A	Torpedo boat	42·2	·432	12·50	2·74
11	Torpedo boat	42·5	—	12·80	—
11A	Torpedo boat	44·6	·457	10·88	3·13
12	Wiborg (torpedo boat)	45 3	·416	11·93	3·19
12A	Vesuvius (cruiser)...	51·6	·436	10·73	3·86
13	Paddle steamer	52·8	·574	10·40	3·09
14	El Destructor	54·0	·448	12·99	3·25
15	Vesuvius (cruiser)...	54·2	·453	10·73	3·92
16	Paddle steamer	54·3	·447	10·70	3·98
16A	Paddle steamer	54·8	·536	10·70	3·34
17	Paddle steamer	55·2	·448	10·92	3·95
18	Wiborg (torpedo boat)	57·7	·467	11·93	3·63
19	H.M.S. Sharpshooter	60·4	·502	11·74	3·59
19B	Le Tronde (cruiser)	61·0	·473	10·03	4·49
21	Tripoli (cruiser)	63·3	·455	11·30	4·30
22	Rosales (gunboat)...	64·4	·453	12·50	3·98
23	Espora (gunboat)	64·7	·453	12·50	3·99
24	Tripoli (cruiser)	65·9	·460	11·30	4·43
24A	Teutonic (Atlantic liner)... ...	66·5	·497	10·18	4·60
25	Tripoli (cruiser)	68·3	·465	11·30	4·55
26	City of Rome (Atlantic liner) ...	70·3	·649	9·58	3·96
27	Arizona (Atlantic liner)	70·4	·589	10·03	4·17
27A	Piemonte (cruiser)	72·8	·472	11·69	4·62
28	Paddle steamer	76·1	·382	13·00	5·36
31A	Yacht	79·2	·383	13·06	5·53
31B	Umbria (Atlantic liner)	78·9	·568	11·40	4·27
32	City of Paris (Atlantic liner) ...	79·8	·575	12·00	4·05
33	Pembroke Castle (liner)	80·2	·623	10·50	4·25
34	Servia (Atlantic liner)	80·2	·610	10·10	4·52
34A	Fürst Bismark (Atlantic liner ...	80·4	·549	11·44	4·48
35A	Neuvo de Julio (cruiser)	81·6	·482	12·57	4·71
36	La Normandie (Atlantic liner) ...	82·3	·614	10·87	4·31
37A	Normannia (Atlantic liner) ...	84·0	·583	11·45	4·40
38	Aurania (Atlantic liner)	84·8	·575	12·13	4·25
38A	Lahn (Atlantic liner)	85·6	·558	10·94	4·91
39	Elbe (Atlantic liner)	85·7	·591	10·65	4·76
40	Oregon (Atlantic liner)	87·5	·599	10·81	4·72
41	Orient (liner)	88·2	·621	10·34	4·80
42	Ems (Atlantic liner)	88·4	·593	10·89	4·79
44	Paddle steamer	88·6	·538	12·67	4·55
45	Aller (Atlantic liner)	88·6	·590	10·96	4·79
46	Screw steamer	89·1	·563	13·16	4·21
46A	Spree (Atlantic liner)	89·7	·594	11·12	4·75

APPENDIX C.—*Continued.*

Number.	Type and Name.	Displacement. (D_m)	Block Coefficient of Displacement. (w)	Breadth. (B_m)	Draught. (d_m)
46B	City of Paris (Atlantic liner) ...	89·8	·561	12·00	4·67
49A	Screw steamer	92·7	·646	10·77	4·67
49B	Yacht	92·5	·333	15·04	6·47
50	Screw steamer	93·2	·650	11·00	4·56
50A	Cinco de Mayo (cruiser)	93·2	·500	13·23	4·92
51	Screw steamer	93·3	·479	13·23	5·16
53	Paddle steamer	93·7	·513	13·06	4·90
56A	Columbia (Atlantic liner) ...	95·7	·569	11·99	4·91
58	Furnessia (Atlantic liner) ...	97·4	·682	10·00	4·99
58A	Yacht	97·5	·372	14·87	6·18
59A	Augusta Victoria (Atlantic liner)	98·2	·574	12·09	4·96
60	H.M.S. Alacrity	98·8	·481	13·00	5·53
61A	Jean Bart (cruiser)	100·4	·496	12·57	5·64
62A	Yacht	102·4	·347	15·58	6·70
62B	Dolphin (despatch vessel) ...	102·2	·467	13·33	5·75
62C	Yacht	102·5	·376	14·14	6·73
63	Stirling Castle (liner)	102·6	·569	11·90	5·30
65	Screw steamer	104·5	·575	12·37	5·14
65A	Yacht	105·7	·405	15·44	5·92
69	Washington	109·0	·596	12·41	5·16
70A	Yacht	109·8	·401	14·93	6·42
71A	Yacht	109·9	·344	16·96	6·62
72A	Yacht	111·1	·368	15·44	6·84
73A	Yacht	112·0	·389	15·45	6·59
73B	Yacht	113·4	·401	14·95	6·66
73C	Yacht	113·6	·353	14·51	7·74
74	Screw steamer	114·9	·519	14·70	5·27
74A	La Cecille (cruiser)	117·9	·567	13·45	5·41
75	America (liner)	118·5	·570	11·80	6·15
75A	Paddle steamer	119·5	·605	12·87	5·36
75B	Yacht	120·2	·408	15·48	6·65
77	H.M.S. Iris...	121·9	·461	15·36	6·03
77A	H.M.S. Iris...	121·9	·461	15·36	6·03
77B	Yacht	122·3	·406	16·43	6·43
77C	Yacht	122·3	·406	16·43	6·43
78	Pinnace	122·5	—	—	—

APPENDIX C.—*Continued.*

Number.	Type and Name.	Displacement. (D_m)	Block Coefficient of Displacement. (ω)	Breadth. (B_m)	Draught. (d_m)
91D	Yacht	143·0	·359	17·05	8·17
92	Screw steamer	143·8	·740	12·60	5·40
92A	Baltimore (warship)	144·0	·519	15·40	6·31
92B	Bennington (warship)	144·0	·520	15·79	6·14
92C	Concord (warship)...	144·1	·519	15·79	6·14
92D	Yacht	145·2	·317	18·60	8·60
93	Cerain (gunboat)	145·3	·487	16·83	6·20
93A	Chicago (warship)	145·3	·551	15·30	6·03
96	H.M.S Scout	146·5	·521	15·46	6·36
97A	Yacht	149·3	·440	16·70	7·20
97B	Yacht	146·9	·376	20·03	6·82
97C	Charleston (warship)	149·6	·523	15·33	6·53
98	H.M.S Medusa	150·5	·547	15·47	6·23
98A	H.M.S. Medea	150·5	·547	15·47	6·23
99	Reina Regente (cruiser)	150·7	·524	15·96	6·31
101A	Atlanta (warship)	153·3	·547	15·60	6·29
102A	Yacht	156·2	·354	18·95	8·18
105	H.M.S. Edgar	158·4	·504	16·67	6·60
105A	Petrel (warship)	159·5	·492	17·72	6·41
107A	Boston (warship)	164·0	·563	15·60	6·54
107B	Reina Regente (cruiser)	165·2	·570	16·45	6·16
110	H.M.S. Blenheim	172·6	·507	17·33	6·87
110A	Yacht	174·7	·426	18·83	7·63
111	H.M.S. Heroine	179·1	·460	19·00	7·16
113A	Libertad (armour-clad)	189·0	·605	19·30	5·65
114	H.M.S. Aurora	185·2	·496	18·67	7·00
114C	Yacht	192·9	·389	18·66	9·33
122	Screw steamer	204·2	·764	13·92	6·75
124	H.M.S. Monarch	224·6	·628	17·42	7·18
125	H.M.S. Edinburgh	225·8	·539	20·92	7·01
125B	H.M.S. Greyhound	226·5	·517	19·22	7·98
125C	H.M.S. Mutine	226·5	·517	19·22	7·98
125D	H.M.S. Ramillies	229·6	·615	19·73	6·62
126	Lepanto (warship)...	231·3	·609	18·16	7·32
127	H.M.S. Captain	234·1	·635	16·64	7·76
128	H.M.S. Collingwood	235·4	·545	20·92	7·23
129	H.M.S. Collingwood	238·9	·547	20·92	7·31
130	H.M.S. Imperieuse	242·3	·556	19·36	7·88
131	H.M.S. Hercules	252·7	·642	18·15	7·59
132	H.M.S. Vanguard	253·5	·613	19·29	7·50
133	H.M.S. Invincible	253·5	·613	19·29	7·50
134	H.M.S. Iron Duke...	253·5	·613	19·29	7·50
135	H.M.S. Sultan	253·9	·639	18·15	7·66
135A	H.M.S. Royal Sovereign	255·8	·631	19·74	7·19
136	H.M.S. Bellerophon	268·0	·629	18·67	7·99
136A	Yacht	270·7	·336	21·32	13·23
137	H.M.S. Bellerophon	271·1	·631	18·67	8·06
138	H.M.S. Alexandra	274·7	·611	19·59	8·04
139	H.M.S. Vanguard	276·8	·625	19·29	8·04
140	H.M.S. Howe	280·7	·572	20·92	8·21
140A	H.M.S. Camperdown	296·3	·589	20·76	8·48
141	H.M.S. Swiftsure	297·8	·599	19·64	8·85
142	H.M.S. Triumph	311·6	·607	19·64	9·15
143	H.M.S. Prince Consort	315·7	·572	21·39	9·02
144	Independencia (warship)	331·5	·672	21·00	8·22
145	H.M.S. Nelson	340·4	·633	21·43	8·78
146	H.M.S. Temeraire	370·2	·629	21·75	9·47

The discussion was adjourned to the following meeting, to be held in West Hartlepool.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893–94.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION, HELD IN THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, NOVEMBER 25TH, 1893.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on Tuesday, November 7th, 1893, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Professor R. L. Weighton and Mr. J. D. Young to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Adamson, Cumberland, Ship Draughtsman, 3, Close Street, Sunderland.
Erdtman, Herman, Engineer, North-Eastern Engine Works, South Docks, Sunderland.
Farrar, Harrie Crawhall, Ship Draughtsman, 18, Gladstone Street, Hartlepool.
Holbrook, Thomas, Marine Engineer, 22, St. Hilda Street, Hartlepool.
McLaren, Robert M., Ship Draughtsman, Flinton Hill, Sunderland.
Moorsom, Frederick, Ship Draughtsman, The Green, Seaton Carew.
Nicholson, John S., Engineer, North View, Mowbray Road, Westoe, South Shields.
Robson, George Edward, Ship Draughtsman, 69, Thornton Street, West Hartlepool.

ASSOCIATES.

Dodds, E. F., Accountant, 36, Side, Newcastle-on-Tyne.

Henzell, Robert, Oil Manufacturer, Old Mansion House, Close, Newcastle-on-Tyne.

Maughan, Thomas, Jun., Cashier and Accountant, Hollyfield House, Sorley Street, Sunderland.

GRADUATES.

Boswell, Cecil Robert, Apprentice Engineer, Northumberland Engine Works, Wallsend-on-Tyne.

Gibson, Thomas, Apprentice Engineer, 162, Roker Avenue, Monkwearmouth, Sunderland.

Jepson, Henry, Apprentice Engineer, 34, St. Mary's Place, Newcastle-on-Tyne.

Wawn, T. Noel, Apprentice Engineer, 6, Belle Vue, Sunderland.

THE APPRENTICESHIP QUESTION FOR SEA-GOING ENGINEERS.

The PRESIDENT said that a circular letter had been issued by the Board of Trade with respect to the time to be served by apprentices to the marine engineering trade. The matter had been under discussion by the Council, and they unanimously agreed to ask Mr. J. R. Fothergill to write a short paper on the subject, so that the members of the Institution might have an opportunity of discussing the whole question, and come to a conclusion as to the reply to be sent to the Board of Trade. Mr. Fothergill had kindly consented to write the paper, and it would be read at the general meeting to be held in Newcastle-upon-Tyne on the 16th day of January next, and after discussion, some resolution would be proposed and sent to

DISCUSSION ON MR. HÖK'S PAPER "ON A METHOD OF COMPARING STEAMSHIP PERFORMANCES AND OF ESTIMATING POWERS AND SPEEDS OF SHIPS.

Mr. W. WEIR, in opening the discussion on Mr. Hök's paper read at the previous meeting, said before commencing to criticise he wished, first, to express his personal obligation to Mr. Hök for his very valuable paper. He had made a careful study of it, and had found it most interesting as well as instructive. Mr. Hök had treated the subject in a most original way, which must have cost him much time and labour. The paper was a very suggestive one, and ought to give rise to a wide discussion. Based upon the assumptions made, it seemed to him that the writer had carried his argument to a logical conclusion, and that in a very clear and masterly way; whether he was justified in these assumptions, was, however, another matter, and he ventured to think it was open to question. With regard, then, to the primary question, "What elements of form and size affect chiefly the resistance of ships at given speeds?" Mr. Hök said it seemed to him that at low speed the surface played a more prominent part than displacement, and at high speeds or at speeds where the wave-making element predominated, first place must be given to the displacement, and, finally, he fixed on the displacement as being the most important factor and took it as his basis of comparison in determining the resistance. Now he thought it had been clearly established by various authorities on the subject that the chief elements of resistance referred to were twofold: (1) Resistance due to friction depending on wetted surface; and (2) Resistance due to wave-making depending on form. Displacement, therefore, could not be said to be a true measure of resistance, inasmuch as it did not indicate either the wetted surface or the form of the ship. On the other hand, displacement might be taken, as Mr. Hök had done, as a measure of fineness, but fineness could not be taken as a measure of wave-making resistance, as it was evident that for a given displacement they could have an endless variety of forms, varying from a perfectly square midship section with fine ends to a V-shaped midship section with parallel water-lines and peerfectly square ends. In the paper referred to by Mr. Hök, Mr. Froude had made use of displacement for comparison for special purposes, but for the ordinary estimator who had to determine the power necessary to drive a ship at a given speed and

who had probably a very limited amount of reliable data at his disposal, displacement as a measure of resistance seemed to him to be quite inadmissible. If the displacement had to be used at all for the purpose of estimating power, it must be treated as in the Admiralty coefficient, that was by an exponent which brought it to a quantity which would be a measure of the wetted surface. For the purpose, then, of estimating the power necessary to drive a ship at a given speed, it seemed to him from what he had shown, that the method proposed by Mr. Hök was not likely to prove a very reliable one. For some of the other purposes indicated by the writer it might probably be made most useful. To the shipowner who wished to know what power he was paying for per ton of displacement, Mr Hök's curves seemed to give in a simple and graphic form just the information that was wanted. He would now discuss the subject of engine friction correction, as some of the remarks he had to make upon it bore upon what he had already said. Mr. Hök commented on a feature in his speed curves which he (Mr. Hök) thought was as "glaring as it at first sight appeared inconsistent," viz., that fine ships had a high expenditure of power at their lower speeds. No doubt this at first sight appeared inconsistent, but he thought Mr. Hök must look for some other cause than engine friction to account for it. It was well known that for such low speeds as 4 to 5 knots, the skin resistance might be taken as constituting the whole resistance to be overcome in driving a ship through water, and that even for such moderate speeds as 10 knots the skin resistance was from 70 to 80 per cent. of the whole. Now, the form of body which gave the greatest wetted surface per unit of displacement was evidently that which had length and depth but without breadth, and the finer the ship the nearer would it approach this form. It was quite clear from this,

took 35 per cent. more horse-power per ton displacement to drive her than the coarser one. From this he thought it was evident that the "anomaly" referred to by Mr. Hök was explained by the fact that the wetted surface per ton displacement increased with fineness, the engine friction only accounting for a comparatively small part of it. This, he thought, also clearly showed that displacement could not be taken as a measure of resistance. Let them imagine a ship such as that he had already referred to, having length and depth and the smallest measurable breadth. This ship would have wetted surface equal to its length by twice its depth. If they doubled the breadth they doubled the displacement, but the resistance would remain practically the same, and consequently the indicated horse-power per ton displacement would be reduced by one-half, while the actual indicated horse-power necessary to drive the ship remained practically constant. With further reference to the subject of engine friction correction Mr. Hök said that owing to the present imperfect state of knowledge he was compelled to make the assumption that the screw efficiency was constant at all speeds for the same ship. Here, again, he thought Mr. Hök had fallen into error, and if he would refer to Mr. Barnaby's book on marine propellers he would find the following statement :—"For a screw of any given pitch ratio there is a particular slip ratio corresponding to its maximum efficiency. A greater or less amount of slip than this will result in a smaller return of useful work in proportion to the power expended in driving the screw." In practice it was found the slip varied with every change of speed, 5 per cent. in one knot being common enough, and from this it was evident that the efficiency was not constant at all speeds for the same ship. Mr. Hök again referred to engine friction, and called attention to the fact that the curves corresponding to certain numbers given showed comparatively high powers at low speeds owing to relatively large machinery. In the table given on the following page he had tabulated a number of the ships referred to by Mr. Hök, and in addition to the information given in Appendix C he had added, for his purpose, two more columns, showing the wetted surface and the wetted surface per ton displacement. If they referred to these figures they would notice that at the top of the column $\frac{S_m}{D_m}$ was 39, and that it gradually diminished as they went down till it reached the very low figure of 9·0, which showed that the wetted surface per ton displacement increased the greater the degree of fineness. The inference to be drawn from this was, he thought, that for all speeds up to which the wetted surface formed the chief element of resistance, fine ships were likely, by Mr. Hök's method,

to show inferior performances, and the inverse was to be expected from ships of greater relative displacement. Nos. 1, 4, and 6 were examples of inferior performances attributed by Mr. Hök to shallow draught, and Nos. 10, 10A, 19, and 32 to relatively large machinery. But these numbers being near the top of the column the excessive wetted surface was, he thought, sufficient to account for the inefficiency. Nos. 143 and 145 on the other hand being at the bottom of the column good performances might be looked for, and inferior performances in these cases rather pointed to inefficiencies of machinery. With regard to the example given in Appendix D he would like to ask Mr. Hök how he had arrived at the factor ·837 (p_D)? As it was carried to three places of decimals it implied great nicety of choice. If on the Diagram 9, Plate IX., referred to in the paper, an ordinate was drawn through the speed 9·58 it intersected the abscissa drawn through 8·37 on the curve No. 140. Referring to Appendix C he found this ship was widely different from the one under consideration, whereas those ships 65, 32, etc., which were more nearly similar gave p_D factor ranging from about ·87 to 1·1. He just wished to say, in conclusion, that in making these remarks, he was fully aware that he might have fallen into error through misunderstanding, and if Mr. Hök could put him right in the matter he thought it might perhaps help towards a clearer understanding of the paper.

Number	Displacement. D_m.	Block Coefficient of Displacement. ω.	Breadth. B_m.	Draught. d_m.	Wetted Surface. S_m.	Wetted Surface per Ton Displacement. $\frac{S_m}{D_m}$.
1	26·6	·536	15·00	1·15	1,033	39·0

The SECRETARY read the following :—

COMMUNICATION FROM MR. R. E. FROUDE.

DEAR MR. DUCKITT, *November* 16*th*, 1893.

I am indebted to the courtesy of Mr. Hök for the perusal of an advance proof of the paper on a method of comparing steamship performances, read by him before your Institution.

The paper strikes me as a most painstaking, sound, and well-directed contribution to a very important study, namely, the instructive comparison of the results of steam vessels of all types and sizes.

The method pursued with this object at the Admiralty works, Haslar, as described by me in the paper read before the Institution of Naval Architects, in 1888, and referred to by Mr. Hök, amounts in effect to reducing all vessels to a common standard unit of displacement, and comparing their then resistances (or powers) stated in terms of speed ; the comparison being effected by diagrams in which either the length or the speed of the model of unit displacement are alternatively used as the base scale.

Mr. Hök, on the other hand, reduces all vessels to a common standard unit of length, and compares their then powers stated in terms of displacement, the comparison being effected by diagrams in which the speed of the model of unit length is used as the base scale. I can readily suppose that for many problems this latter principle of comparison may be the more convenient of the two.

At the same time, did I find myself led to have recourse to Mr. Hök's principle of comparison, I think I should prefer to cast it in a slightly different form, which appears to me to be more workable and in some respects simpler. This I will describe, if I may, premising that the particular methods in which given principles of comparison are carried out are to a great extent matters of taste, and that I do not presume to quarrel with anyone who prefers Mr. Hök's arrangement to my professed emendations on it.

Speaking for myself, then, I should suggest the following successive degrees of, as I think, emendations on Mr Hök's arrangement :—

In the first place, observe that if the two terms in Mr. Hök's equation (6), are kept separate, the final equation ($6\frac{1}{2}$) becomes

$$p_D = \frac{I}{D\sqrt{l}} - q\tau \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(i.)}$$

Here the first term, which is *the* important one, is simply $\frac{1}{D}$, (or the

value of p_D for the ship) divided by $\sqrt{l}$, and may be computed almost by a stroke of the pen. The remaining term, representing the friction correction, is always small, and sometimes negligible; and it seems to me much better (and safer against mistakes) to compute the important quantity by the above simple expression and take the correction separately, than to pass the whole quantity unnecessarily through the mill of U and τ. In my equation U disappears altogether, and τ is only required for the small corrective term.

In the second place, for computing this corrective term, I should much prefer to substitute for q another coefficient, say Q, where

$$Q = \frac{q^*}{V^3_m} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(ii.)}$$

This with the sole object of making the value of the coefficient more nearly constant, so that the curves of the diagram expressing it (see Diagram 1, Plate I.) may lie closer together, more conveniently for interpolation between them for intermediate length values. Indeed, with the aid of this divisor, the coefficient will become so constant for varying speed, that for very many cases, Q might be sufficiently expressed by a single curve to a base of varying length, for some medium speed. [The ordinates of this curve would be proportional to the values of O (of the table in my Institution of Naval Architect's paper—see Mr. Hök's Appendix A, page 36), for length L, *minus* the value for 100 feet length.]

But, thirdly, accustomed as I am to the comforts of the system used at Haslar, I should be for an extension of the same expedient, in order to avoid the tremendous variation of ordinate value of the curves of p_D (see Diagrams 2 and onwards), towering out of the paper as they do, at one end, yet too small to measure accurately at the other. Nor can we say here as

negligible, while the additional labour in computation of the first term due to the V^3 in the divisor is, as I think, amply repaid by the convenience of the approximate uniformity of value of p_D.

But even so, I fear I should still bear a grudge against the presence of l in the numerator of the first term, as well as in the expression for τ. This is to be got rid of by substituting $D^{\frac{2}{3}}_m$ for D_m in the divisor, when we get

$$p_D \left(= \frac{I_m}{D^{\frac{2}{3}}_m V^3_m}\right) = \frac{I}{D\ V^3} - Q \frac{S}{100D^{\frac{2}{3}}} \quad . \quad . \quad . \quad . \quad \text{(iv.)}$$

Mr. Hök's professed object in introducing displacement into the divisor is to approximately eliminate the effect of differences in the displacements of ships of equal lengths, and this object will in theory (and for moderate speeds in fact) be more correctly achieved by using the two-thirds power of the displacement, as here proposed. The change therefore involves no departure from principle but rather the reverse.

It will be observed that our first term (which is the whole value of p_D neglecting skin friction correction) has now become simply the reciprocal of the venerable Admiralty displacement "constant;" and it seems to me that in cutting out the V^3 and substituting D for $D^{\frac{2}{3}}$, Mr. Hök has in reality been dismissing an old and faithful servant without sufficient cause.

It will also be noticed that in place of τ we have now got a new coefficient—

$$\frac{S}{100D^{\frac{2}{3}}} = \Sigma, \text{ say} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(v.)}$$

This coefficient corresponds to the coefficient S of my Institution of Naval Architect's paper, and is independent of scale for given form. Further, it is approximately independent of form for given general proportions, while it varies but moderately with variations of proportion, and for any vessel of ordinary character it may be expressed by the formula

$$\Sigma = \cdot 357 + \frac{L}{60D^{\frac{1}{3}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(vi.)}$$

with accuracy abundantly sufficient for purposes of determining skin friction correction. An equivalent formula is in fact often so used at Haslar for the correction required in passing to large ships from the 14 feet models used in the experiments, which, of course, requires a much greater percentage accuracy than does the correction from Mr. Hök's standard 100 feet model. This constant Σ is in itself a generally convenient one to use and have on record as characterising the proportionate amount of wetted surface of the design.

We thus get as the final formula, which I recommend as most suitable for Mr. Hök's principle of comparison—

$$p_D = \frac{I}{D^{\frac{2}{3}} V^3} - Q\Sigma \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(vii.)}$$

and comparing this with my simplified version of Mr. Hök's formula in equation (i.) above, we see that the only additional complications introduced have been the V^3 in the divisor, and the D *vice* the simple D. Against these have to be set the following advantages:—

(1) $\sqrt{l}$ expunged.

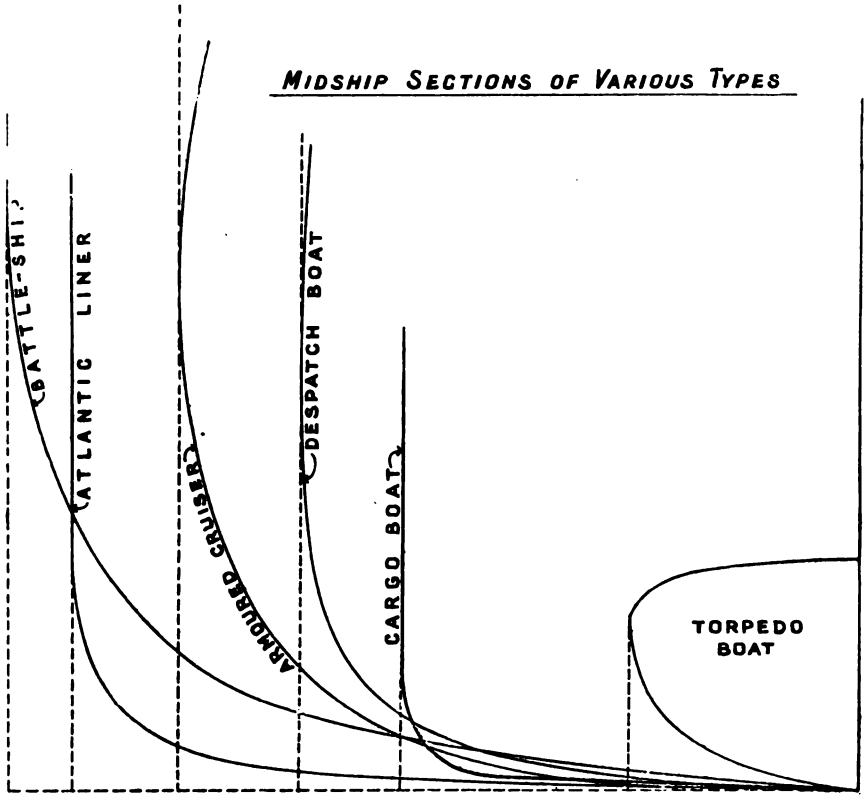
(2) A diagram of Q much easier to compute from than Mr. Hök's diagram of q.

(3) Instead of the coefficient τ, which requires a computation of wetted surface, we have the generally convenient coefficient Σ, so nearly constant that it may often be assigned by guess quite accurately enough, and can in any case be determined by the simple formula of equation (vi.) without any express computation of surface.

(4) Much flatter and more convenient final curves of p_D.

Speaking generally, I would urge this consideration in favour of adjusting formulæ so as both to use and yield values which approach constancy, namely, that the values can then be carried in the head with serviceable correctness. I have already drawn attention to this advantage attaching to the coeffieient Σ. The same consideration applies to the values of p_D, and in merely speaking of these above as giving "flatter and more convenient curves," I do not think I have done full justice to the advantages of formula (vii.). For the variations of ordinate are so far moderate that the value of p_D for such or such a type

comparisons were made, he thought that vessels of nearly the same size should be compared and the comparisons based upon ships of somewhat similar proportions. If this was not done, there would be considerable error in the approximate calculations, and this would be more likely to occur when block coefficients were used of different dimensioned vessels, as these coefficients would not then bear a true relation to each other. To more clearly explain this he had prepared a number of midship sections of different vessels (see sketch) mentioned in the paper, and, he thought,



even if these ships or sections were reduced to the 100 feet model, the likelihood of error would still remain. Mr. Hök had paid the Government a very great compliment for what they had done in increasing the speed of their ships, but in his (Mr. Sivewright's) opinion if shipbuilders had the same amount of money and latitude to design ships they would do quite as well as any Government. He noticed that Mr. Hök had strongly recommended an increase of beam to get more speed out of ships.

He (Mr. Sivewright) thought that an increase of beam in a Government ship was quite a different thing to what could be done in ships for commercial or cargo purposes. The members would notice that big-beamed ships built for the Government (carrying no cargo) had practically all their bilges cut away, whereas when beam was added to an ordinary cargo steamer it was carried well down to the bottom of the vessel and was a different section altogether. Speaking as a shipbuilder, he had always thought there was far too much reliance placed upon measured mile trials made in smooth water. Were speeds of this description, got under most exceptional circumstances, a proper measure of comparison with regard to the everyday trading of vessels? Indeed, he would go further, was the published data of speeds always to be relied upon? It would afford a good test of the speed and sea-going qualities of some of the big-beamed Government ships if they were run continuously at full speed over a voyage, the same as is done by the Atlantic liners and other passenger steamers.

Prof. R. L. Weighton, M.A., said he thought the basis upon which Mr. Hök had gone in his paper was perfectly sound, and the only point that he should be inclined to take exception to would be the sweeping nature of some of the deductions at the end. He did not think that there was anything to be said against the general method of treatment adopted in the paper—that was, reducing the different ships to one denominator as regarded length. But when they considered that the long list of trial data was got from very different sources as regards trial conditions, and with the individual circumstances of each of which they were unacquainted, he did not think even comparative deductions could be

and speeds without having too much time in which to do it, there was a shorter way. From the progressive trials of a ship, a curve, the abscissæ and ordinates of which were speeds and powers, could always be laid down without the need of any fresh calculation. Now, suppose they had to estimate the power, P_1, required to drive a similar proposed ship at a given speed, V_1. Let the length of the proposed ship be L_1, the length of the type ship be L, and the speed of the type ship corresponding to V_1 of the proposed ship be V, the procedure would be as follows :—

1. $\frac{L_1}{L} = l =$ ratio of dimensions.
2. $V = \frac{V_1}{\sqrt{l}} =$ corresponding speed of type ship.
3. From the speed and power curve of type ship, find by inspection the power P which was required to drive her at speed V.
4. $P_1 = P\, l^{\frac{7}{2}} =$ power required to drive proposed ship at speed V_1.

They had only the four steps, viz.:—(1) Find the ratio of the lengths, l; (2) find the corresponding speed of the type ship; (3) find the power for this speed by inspection; and (4) find the required power of proposed ship. Now, he did not think there could be anything simpler than that, and he was sure it would be interesting to the meeting if he read a sentence or two from a letter he received the other day from Mr. John Inglis, President of the Institution of Engineers and Shipbuilders in Scotland, a gentleman who, next to the late Mr. William Denny, had been the means of popularising progressive trials of steamships. Mr. Inglis said :—"I have glanced over Mr. Hök's paper, which is full of interesting data. I think he comes pretty near the lines of a paper of mine read in 1877 before the Institute of Naval Architects. Then and afterwards it was common enough here to reduce ships to similar displacements to get at the relative performances. But now, instead of having a lot of trials reduced to a sort of common denominator, we generally pick out a type ship from the recorded trials and work from that; and I think it is the easiest way. We have now about 1,000 runs on the measured mile to choose from. . . . . I am thankful to say that I don't believe anybody will ever devise a means of accurately estimating speeds of steamers, and I am content to take my chance of hitting or missing with ordinary mortals. Nothing can supersede careful trials and accurate records." This was the opinion of no mean authority in the matter of steamship propulsion. He (Prof. Weighton) hoped Mr. Hök would not misunderstand him; he did not find fault with the principle

of analysis expounded in the paper. But he thought there was a simpler way of estimating—not necessarily for analysing. The corrections for engine friction and for length of surface could be made by Mr. Hök's method or otherwise, but, as Mr. Weir had well pointed out, compelled as they were to assume an equal propeller efficiency for all speeds, the variation in skin friction due to length seemed really a matter of comparative unimportance. There was another point he thought deserved consideration, that was, the relation between the coefficient of fineness and speed. He was inclined to think that as Mr. Hök gathered more experience he might alter his views with regard to that matter. In justice to Mr. Hök it must be noted that he refers to the table on page 33 of the paper as giving only a "faint indication of the fineness appropriate to speed." He (Prof. Weighton) had calculated the speeds appropriate to ships of 500 feet long for various coefficients of fineness on Mr. Hök's basis, and these are shown in column A in annexed table, the speed for $w = \cdot 8$ being taken at Mr. Hök's value in each case :—

Coefficient of Fineness. w.	Knots per Hour. A.	Knots per Hour. B.
·8	12·2	12·2
·7	15·6	16·9
·6	20·	20·5
·5	26·7	23·7
·4	37·9	26·4
·3	53·5	28·9

It will be observed that for $w = \cdot 3$ the speed reaches the enormous

of course, mean the minimum horse-power per ton of cargo delivered at a given speed. And this is quite a different thing from displacement basis as a measure of efficiency. He thought Mr. Hök should make it clear as to what was precisely meant when he spoke about "progress," because, as it stood on the paper, there seemed just a trifle of doubt about it.

Mr. J. DENHOLM YOUNG thought that they must all agree in admiring Mr. Hök's paper. He did not think he was exaggerating or saying too much when he expressed the belief that the Institution ought to be thankful to have such a paper in its *Transactions*. It was much easier to criticise a paper of this sort than to write it, and he trusted if he did say anything in criticising it, Mr. Hök would not think he was treating him harshly. Of course there was a difficulty in seizing upon some unit of comparison with regard to ships differing so widely in proportion and size. It seemed at first sight that almost any choice would lead to unfair comparisons. He did not think, however, that they should leave out of account that they were brought to one unit length, and approached much more nearly to the same cross-section than appeared from Mr. Sivewright's diagram. Then, as regards the choice of displacement as the unit of comparison, undoubtedly displacement was a handy unit in this method of calculation; but when it came to finding and comparing efficiencies and horse-powers, then I.H.P. per unit $D^{\frac{2}{3}}$ would, perhaps, give them a fairer comparison between two different vessels, because $D^{\frac{2}{3}}$ was a better measure for resistance than simple displacement. With regard to the limit of speed that Prof. Weighton had touched upon, it seemed to him that Mr. Hök had omitted to take into question the ratio of length to breadth, which was a very important factor in determining the limit of speed to which a vessel could be driven. For instance, a vessel of ·7 coefficient and 5½ beams to the length could not be driven, roughly speaking, any faster with ·8 coefficient and 8 beams to the length. Mr. Hök had referred to the large power which some fine boats took for driving at low speeds. Mr. Weir touched upon that point; but he (Mr. Young) thought there was another thing which must be taken into account with some yachts of which they had speed curves. A good many were fitted with feathering propellers. He thought they were not in all circumstances the most efficient means of propulsion, and therefore they must discount something from them. With regard to the correction Mr. Hök had made for engine friction, he thought that an important item, and one rather difficult to arrive at. It had been debated for a good many years, and Mr. Hök had given them a curve—he must take it for granted a correct

curve—of what he had found to be engine friction correction on progressive trials. If one worked out this correction analytically he (Mr. Young) found that it could be given by the following equation :—

$$\mu = 1 - \left(1 - \frac{V}{V_{max}}\right)^2$$

which corresponded almost exactly with one of Mr. Hök's curves. Now, suppose he wished to compare, as Mr. Hök had compared, ships with very different classes of engines: for instance, take a 16 knot vessel, having engines 18 inches, 29 inches, 46 inches, by 30 inches, worked at a high speed, say 120 revolutions, and making at that 1,000 horse-power; compare that with a paddle engine 30 inches and 58 inches by 60 inches, working at about 50 revolutions, and making 1,000 horse-power at 16 knots. They wanted to get at something like the initial friction differing so much in these engines. Instead of taking into account the maximum speed and actual speed they wanted to get at some measure of what they would expect the initial friction to be in these engines. He thought it would depend upon the size of the engines, say as measured by the nominal horse-power. Now, suppose the speed to vary according to the cube root of the horse-power, they could substitute cube root of horse-power for speed, and then the question came, what standard ratio were they to take for indicated to and nominal horse-power? He (Mr. Young) thought it would be best to take the highest probable ratio—somewhat higher even would not matter, say 27 : 1, which would include torpedo boat engines. Taking that, then their correction became :—

$$\mu = 1 - \left(1 - \sqrt[3]{\frac{\text{I.H.P.}}{27\ \text{N.H.P.}}}\right)^2 = 1 - \left(1 - \frac{1}{3}\sqrt[3]{\frac{\text{I.H.P.}}{\text{N.H.P.}}}\right)^2$$

Prof. Wrightson.—What is the nominal horse-power?

Mr. H. WITHY said he desired a little information from Mr. Hök on the point on page 33 referred to by Prof. Weighton, that of the tables of coefficients and speeds at which such ships could be economically driven. He took it from the table that a 400 feet ship with a coefficient of ·8 could not be driven economically over 11 knots. In ordinary practice a steamer intended for a speed of 11 knots would not be more than ·74. His firm was building vessels of 5,700 tons displacement at a coefficient of ·78, and they were driven about 9 knots with 13 to 15 tons of coal per day, and they considered this the maximum speed that could be economically obtained from such vessels, yet Mr. Hök spoke of ·8 coefficient for an 11 knot speed. Could a higher speed than 9 knots be reasonably expected from a vessel having a coefficient of ·78 ?

The PRESIDENT observed that the question of speeds was always one of great interest, and while Prof. Weighton had professed to be in the dark as to the nominal horse-power, he, as a shipbuilder, had often been in the dark as to what indicated horse-power really meant. He was once talking to an engineer, not far from Hartlepool, about powers, and he said if they took away the propeller the engine might indicate anything they liked. He found in practice a great difference in the relative values of nominal and indicated horse-power, and the effective power for driving a ship. There was a power engineers seemed to aim at which would bring the coal consumption down to 1·4 lbs. per indicated horse-power per hour, but this power did not appear to assist the speed of the ship. That which concerned them all was, what was the best speed, on a given deadweight, that they could get on the most economical consumption of fuel? He had a steamer which was exercising his mind. She was a full boat of ·79 displacement coefficient, and carried 4,300 tons, consuming 19 tons of coal for 9 knots maximum. They had reduced the speed to 8 knots and she burned 12 tons. A sister ship, with 10 horse-power nominal less, went 9 knots on 15 tons of coal. There was a case in point where they were burning 4 tons of coal per day to no purpose. He built a ship some years ago, and afterwards a sister ship, except that they put one foot more beam amidships, they kept the ends the same and took off the long straight side. The latter vessel carried more deadweight, had the same sized engines, with slightly larger boilers and coarser pitched propeller, and steamed about half a knot faster. He considered that the alteration of boilers and propeller might account for one quarter knot increase of speed, and that one quarter knot was due to the increased beam with comparatively finer ends, a circumstance which might be useful to Mr.

Hök in giving his reply. He recently built a vessel which had given very satisfactory results, and had undertaken to build a similar one for some friends; the length being the same, but the beam increased by 1 foot 10 inches, and the depth reduced so that the draught would be 8½ inches less. He expected to get a slightly better speed out of the broader ship with the same engine power as in the original. That brought them to the question of the proportion of beam to length, referred to by Mr. Young, in low speed ships of 9 to 9½ knots. He did not think the value of a paper consisted wholly in its length, but a good deal depended upon the discussion, and the kind of discussion. He was sure Mr. Hök must be gratified by the way his paper had been taken up, and the information brought out. He hoped Mr. Hök in his reply would give them some further information that would add to their present knowledge.

Mr. J. R. Fothergill thought this paper offered a favourable opportunity to refer to the misleading expression—"coefficient of fineness." He used the word misleading as referring to unpractical men, and particularly in reference to shipowners generally. To the naval architect or the shipbuilder the expression was plain, and simply meant length, breadth, and draught into displacement, or the ratio the volume of the displacement bears to the block circumscribing the immersed body, but to unpractical men it unfortunately conveyed a sense of the fineness of the bow. In fact, it was an everyday experience to hear a shipowner referring to some new ship as too bluff, or too fine, based on the coefficient of fineness being ·8 or ·76. He admitted they would not be far wrong in reference to known ships built by the same firm on proportional dimensions, but suppose a shipowner was asking quotations from, say, half a dozen firms in different districts the chances are he would be entirely

as to fineness, which might not be right at all. One shipbuilder he heard of took the draught, to obtain the block coefficient, to the bottom of the keel; another took the shell plating into account. These block coefficients alone were of little value as to the vessel's steaming qualities. There was no doubt that many people who had not taken the trouble to understand the meaning of the coefficients, and who tried to make comparisons from them alone, found the results very misleading; because shipbuilders could so alter the midship section and ends of a vessel that the block coefficient alone did not indicate the true fineness of the water-lines. They might have a fineness of the midship section with full ends, or fuller midship section with finer ends, but the same block coefficent in each case. If they took a block coefficient of ·76 on 14 feet draught, and ·76 on 16 feet draught, they would get very different results; and the relative value of these coefficients with 2 feet less draught was quite discernible on a model to the naked eye. If an owner was talking about ·76 coefficient he would never think anything of the altered lines, which materially affected the speed. He therefore agreed with Mr. Sivewright in stating that if owners were to put themselves more into the hands of the builders, say in ordering a ship to carry 4,000 tons at 9 knots, and ask what was the best they could give them, it would be better than to say "Build a ship like so-and-so." The results would be more satisfactory than they were at present.

Mr. A. McGlashan wished to say how much he appreciated the great labour of Mr. Hök in getting up such a paper. He thought probably for practical purposes Mr. Hök had done right in retaining displacement as the principal factor in estimating speed and engine power required. When comparing the amount of wetted surface in one ship having a given displacement, with that in another ship having the same displacement but different proportions of length, breadth, and draught, it was easy to show by assuming an impossible ship, having length and depth but little or no breadth, the great difference there might be in the amounts of their wetted surfaces, and by that comparison to show how errors might occur in estimating speed or power from taking only displacement and not wetted surface into account. But there was not the same disproportion between wetted surface and displacement in ordinary ships, because the proportions of length, breadth, and draught did not, after all, vary to such an extent. Besides, the displacement was usually known for a vessel and was therefore a convenient quantity to use in estimating; and he thought the mass to be driven at a

given speed would naturally be the main factor used in estimating the power required to drive it. Other things had to be taken into account, and these Mr. Hök had noticed. For instance, how the surface friction resistance per unit of wetted surface decreases with increased length of ship. Of course, the wetted surface for taking into account the skin friction resistance was an element in the problem, but it and other elements were usually proportionate to a function of the displacement. It had been pointed out in the discussion that the usual block coefficient of displacement did not indicate exactly the comparative fineness of the ends of vessels, and that was quite true when their coefficients of immersed midship section areas were different. Suppose an extreme case: if one vessel had a displacement coefficient of ·72, and of immersed midship section area of ·9, the coefficient of fineness of the ends would be ·72 ÷ ·9 = ·8; while another ship, having the same coefficient of displacement, ·72, but with that of immersed midship section area ·8, the coefficient of fineness of ends would be ·72 ÷ ·8 = ·9, which would be much less suitable for driving at a moderate speed than the other, though both had the same displacement coefficient. He thought the reason why the mean angles of the entrance and of the run of vessels were not usually recorded or spoken of was because there was not any rule by which they could use them to advantage in computing speeds and engine powers. For many years attempts had been made to form such rules, but those tried had not been more successful than the usual methods of calculation. The old Admiralty formula was still useful for ordinary estimates when dealing with vessels not differing very widely from other vessels, the performances of which were known. He very much valued the information given in Mr. Hök's paper as to the actual speed performances of a wide range of ships, and he thought

of these speeds, and he had better point out that they were not the most economical speeds by any means as some speakers understood them to be. They would see by referring to the paper that what he really said was that these speeds should on no account be exceeded, which was a very different thing indeed. Apart from that, the table was necessarily a very approximate affair, and what he wanted to convey by it was the intimate connection between speed and fineness. He also wanted to say a word respecting Mr. Froude's communication, which was to this effect: that the first equation (i.) in it was a distinct improvement on his (Mr. Hök's) own method. He received Mr. Froude's communication about a week ago, and now he had much pleasure in telling them that he had been able to simplify his own method to a very great extent. They would find by referring to his paper that he had to calculate three quantities U, S, and τ. Mr. Froude showed how to get rid of U, and in this lay the great value to him of Mr. Froude's equation (i.). Since then he (Mr. Hök) had succeeded in simplifying still further his method, and had been able to do away not only with the wet surface S but also τ (the latter at least for all purposes of calculation). So to use the method in its simplified form they did not, practically speaking, require to calculate anything at all. They had only to take from Diagrams 9, 10, or 11, Plates IX., X., and XI., what he called p_D, which was the indicated horse-power per ton of displacement for 100 feet model, then from Diagram 1, Plate I., take the skin friction correction q, then τ from a third diagram consisting of a single curve, which he was going to add to the paper, multiply q by τ, add $q\tau$ to p_D, and multiply the sum $p_D + q\tau$ by displacement $\times \sqrt{l}$. This was now the whole calculation. He merely wanted to give notice of this simplification now. He intended to make an addition to the paper, which would be found in his reply proper explanatory of the way he had deduced his new method. He thanked them very much for the spirited discussion and their kind appreciation of his paper.

The discussion was adjourned.

THE DANGEROUS WORKING HEAT OF MILD STEEL, AND THE EFFECT OF ANNEALING AND AIR COOLING.

By JOSEPH NODDER.

[Read before the Institution in West Hartlepool, on Saturday, November 25th, 1893.]

The more general use of Siemens-Martin steel for boiler purposes is perhaps limited by fifteen years. In its early days it was looked upon with considerable misgivings, which even to-day exist in the minds of not a few boilermakers and engineers, and the references to the "iron plates of years ago," and the fitful questioning about "high tensiles" and "low tensiles"—the questioner meaning by the first 30 tons tensile, and by the latter 26 tons tensile—all go to show that the knowledge of the failures of Siemens steel are matters of wider acquaintance than the causes of such failures, the steel and the steel-maker frequently receiving the blame that should be given to other people.

The most reliable and satisfactory results from Siemens-Martin mild steel are obtained from material of 26 to 30 tons tensile, and not less than 20 per cent. elongation in 8 inches, the distinction between high and low tensiles within this limit being a fallacy. Steel of 26 tons tensile or 30 tons tensile can be produced from the same ingot almost at the will of the plate roller, certainly without any variation of the chemical constituents of the material, and the same failures can be produced by mechanical treatment in steel plates anywhere from 24 tons to 30 tons tensile strain to the square inch.

Basic and Bessemer steels are subject to the same weaknesses, though Bessemer steel develops faults in working out of a fire that make it unsuitable for general boiler work, and its use is very limited. Basic steel, if made on the open-hearth system, gives very similar results to the Siemens-Martin steel, as Table III., page 74, of experiments will show; but practical experience has not yet developed sufficient confidence in its use as a substitute for Siemens steel in external and internal flanged boiler work.

An increased elongation, say to 25 per cent. in 8 inches of steel 30 tons tensile would show greater ductility than 24 tons tensile with only 20 per cent. elongation. This is a point that is generally overlooked, a demand being made for a lower tensile rather than an increased elongation. Similarly, much is made of a "flanging test," but the only reliable test of steel is that obtained by the actual measurement of the force applied and represented by the tons tensile and the percentage of elongation.

Bending tests—cold, hot, and quenched—are useful aids, the latter especially, but unless the force used for bending is accurately measured the test cannot be tabulated, and is only of service in conjunction with the tensile tests.

An elaborate series of over 500 experimental and comparative tests of Siemens and Bessemer steel and B.B. and Bowling iron were made in 1881 by a very careful Admiralty surveyor, the late Mr. J. F. Barnaby, and from his notes Tables IV., V., and VI., pages 75-77, showing the behaviour of Siemens steel under varying temperatures and continued exposure to flame, are extracted, and it will be noticed that a temperature of 400 degs., or what is known as "black hot," gives the worst results in tensile strain and elongation.

A paper read by Mr. C. E. Stromeyer, of Lloyd's Registry, before the Institution of Civil Engineers in 1886, dealt with the "effects of blue heat on steel and iron," meaning by "blue heat" 470 to 600 degs. Fah., at which heat he concluded there was the most risk in working iron and steel.

Experiments conducted at Messrs. John Brown & Co.'s works in 1892 and 1893 would place the dangerous heat nearer 400 degs. as in the experiments referred to in 1881; and also that Siemens or basic steel

This experiment was repeated upon another plate (experiments No. 15, O 6, and No. 16, P 6); this plate as received from the mill (see No. 10, J 6) gave 27·2 tons tensile per square inch with an elongation of 26 per cent. in 8 inches, but after ten minutes of acquaintance with a heater or a temperature of about 600 degs. and 70 blows from a 9 lb. hammer on an anvil, the result was a rise in tensile to 31·3, and a fall in elongation to 13 per cent. = a loss of 46 per cent. of the ductility; again, repeating the heat of 400 degs. in No. 16, P 6, with a heater for five minutes, and less work on the anvil, the result was a further rise in tensile to 32·3 tons and a further decrease in elongation to 10 per cent. = a total loss of ductility of 61 per cent. It is beyond question that this serious depreciation of the material arose from the heating, for experiment No. 5, mark E 5, after 75 blows from a 9 lb. hammer on an anvil gave but slightly varied results from its original condition, viz., 27·7 tons tensile per square inch as against 27·3, elongation 28 per cent. as against 29 per cent., practically no change.

Test No. 18, R 6, compared with No. 19, S 6, shows the healing effects of annealing upon this material after it had been hardly dealt with by heaters and hammering. These two pieces were subjected to identical treatment, excepting that No. 19, S 6, was afterwards annealed. No. 18 gave 33·4 tons per square inch tensile against No. 19, 28·1, with an elongation in 8 inches of only 9 per cent. as against 28 per cent. of the annealed test, proving conclusively the restorative power of annealing and its necessity and importance as a final process on Siemens steel that has been heated and worked in any way, whether by the manufacturer, or the boilermaker, if failures are to be avoided.

The results of a long series of tests would teach that the heating and reheating of Siemens steel makes little or no difference to the structure of the material when cold, providing no work has been put upon it between 400 and 600 degs., and also that steel may be hammered and bent cold without detriment.

Annealing is another of the vexed questions that surround steel, and the effect of air cooling has been the basis of much theorizing upon the causes of failed furnaces, tube plates, etc. Wholesale deterioration by over annealing has also been charged against this material, and a reference to a series of tests in Tables I. and II., pages 72 and 73, will be of service. Test No. 9, I 6, was left in the annealing furnace 4 hours, heat of furnace 1,500 degs. (taken by Siemens's galvanometer), afterwards cooled in open shop, the result was a decrease of tensile from 27·2 to 26·2 tons and an increase of elongation from 26 per cent. to 32 per cent. (compare No.

10, J 6, with No. 9, I 6). Various modes of heating and cooling were tried on plate No. 7. Experiments 20 to 28, Table II., No. 26, G 7, shows the original condition of plate as received from the rolling mill with a tensile of 27·5 tons per square inch and an elongation of 34 per cent. in 8 inches. No. 20, A 7, heated to 1,100 degs. and cooled off on the railway side—an exposed place—with the temperature at 45 degs. still gave a tensile of 27·5 and an elongation of 33 per cent., and No. 25, F 7, heated to 1,500 degs. in a coke fire, and then cooled off in four minutes by cold blast at 10 lbs. pressure, gave a tensile of 28·0 tons per square inch, and an elongation of 27 per cent., while the annealing, re-annealing, and cooling four times in succession of test No. 12, L 6 (compare with No. 9, I 6), gave a decrease of ¼ ton tensile and an increase of 4 per cent. in elongation. The whole results clearly prove that air cooling, even under extreme variations of temperature, can make no appreciable difference to this class of material.

The same cannot be said of water cooling, and a comparison of tests No. 1, A 5 and No. 3, C 5, show a marked change, and an increase of 10 tons per square inch tensile, with a decrease of 51¾ per cent. of elongation, after heating to 1,500 degs. and cooling in water at a temperature of 60 degs., making the material quite unfit for service without again reheating.

Different kinds of work put upon tests No. 6, F 5; No. 7, G 5; No. 8, H 5; and No. 17, Q 6, and a comparison with original conditions in No. 1, A 5, and No. 10, J 6, will teach that whatever the class of work, whether flanging as in Nos. 7 and 8, or the violent distortion of structure by "jumping up" the thickness of No. 17, the material, if annealed after working, is as good as ever. No. 6, F 5, was only partially heated, and in that condition worked equally over the whole of its

be verified at any time. In fact he should like very much if those who had the opportunity would repeat the experiments for themselves. As regarded Messrs. John Brown & Co. and basic steel, they did not use it at all, but he was asked to try what a similar series of experiments would show on basic as compared with Siemens, and that was the reason why it appeared. A few days ago he heard from Mr. Milton, who seemed to think it would be more to the purpose if he had taken a much lower tensile Siemens steel. They had heard something about Siemens steel of 22 tons tensile; but in his view it was not an article that was on the market. They had got Siemens steel as low as 24 tons, and he hoped at some early date to repeat the experiments on it, and show conclusively that, no matter what the tensile strength might be, if they worked steel at a heat between 400 and 600 degs., they ran the tensile up unduly, and necessarily decreased the elongation, which he took to be the real measure of the ductility of steel, that is, elongation within a certain length.

WITH SIEMENS' STEEL AT MESSRS. JOHN BROWN & CO.'S, LIMITED, 1892-3.

er.	At Point of Fracture. Size.	At Point of Fracture. Area.	Reduction of Area per Cent.	Elongation. In 8 Inches.	Elongation. Per Cent.	Treatment.	
	1·08 × ·42	·453	54	"	29	As received from mill.	
	1·05 × ·41	·430	55	"	30	Heated to redness (say 1,550 degs.). Annealed in ashes.	Heated in breeze fire.
	1·20 × ·51	·612	38	"	14	" " " " Quenched.	
	1·18 × ·45	·531	43	"	8	Heated with heaters (about 5 min.), and hammered (not annealed).	
	1·08 × ·41	·442	54	"	28	Hammered cold on anvil (say 75 blows) (not annealed).	
	1·12 × ·26	·291	48	"	18	Partially heated in fire (half length) and hammered (not annealed).	
	1·12 × ·23	·257	54	"	27	Heated and worked as in process of flanging.	Heated in blast coke fire.
	1·10 × ·25	·275	51	"	29	" " " " " afterwards heated and stood in sheltered place to cool.	
	1·05 × ·42	·441	54	"	32	Left in annealing furnace 4 hours, heat of furnace 1,500 degs. (taken by Siemens' galvanometer).	
	1·13 × ·42	·474	51	"	26	As received from mill.	
	1·05 × ·42	·441	54	"	29	Heated to white heat in breeze fire. Stood up in sheltered place to cool	
	1·06 × ·42	·445	54	"	30	Annealed and cooled off 4 times in sheltered place.	
	1·21 × ·47	·568	42	"	22	Heated and quenched. Heated to say 1,150 degs.	
	1·28 × ·51	·652	32	"	14	" " " " 1,550 "	
	1·22 × ·48	·585	38	"	13	Heated with heaters 10 min., 70 blows from hammer.	Taken to prove result from D 5
	1·22 × ·46	·561	40	"	10	" " 5 " 60 " "	
	·56 dia.	·246	50	"	24	Jumped up and worked to 1 in. sq. out of breeze fire. (Annealed.)	
	1·23 × ·45	·957	42	"	9	Heated with heaters 4 min., 70 blows from hammer.	
	1·08 × ·41	·942	52	"	28	" " " " " Afterwards annealed.	

CHEMICAL ANALYSIS.

arbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
·19	·02	·06	·055	·55
·20	·02	·06	·056	·52
·20	·02	·06	·055	·54
·20	·03	·08	·05	·68
·20	·03	·08	·05	·65
·19	·03	·08	·049	·65

TABLE II.

Experiments with Siemens Steel at Messrs. John Brown & Co.'s, Limited, 1892-3.

Annealing and Air Cooling.

No.	Mark on Test.	Original Section of Test Piece.		Breaking Strain.		At Point of Fracture.		Reduction of Area per Cent.	Elongation.		Treatment.
		Size.	Area.	In Tons.	Tons per Sq. In.	Size.	Area.		In 8 Inches.	Per Cent.	
20	A 7	1·53 × ·64	·979	27·00	27·5	1·08 × ·43	·464	52	„	33	Heated to 1,100 degs. in annealing furnace. Cooled in exposed place in open air. Temp. 45 degs.
21	B 7	1·53 × ·65	·994	28·00	28·1	1·10 × ·43	·473	52	„	29	Heated to 1,500 degs. in annealing furnace. Cooled in exposed place in open air. Temp. 45 degs.
22	C 7	1·53 × ·64	·979	26·75	27·3	1·07 × ·38	·406	58	„	32	Heated to 1,500 degs. in annealing furnace. Cooled in open shop.
23	D 7	1·53 × ·65	·994	26·50	26·6	1·09 × ·40	·436	56	„	33	Heated to 1,100 degs. in annealing furnace. Cooled in open shop.
24	E 7	1·53 × ·64	·979	26·50	27·0	1·07 × ·39	·417	57	„	33	Heated to 1,500 degs. in annealing furnace. Cooled off in breeze ashes.
25	F 7	1·53 × ·64	·979	27·50	28·0	1·08 × ·40	·432	55	„	27	Heated to 1,500 degs. in coke fire. Cooled by cold blast (10 lbs. pressure) in 4 minutes.
26	G 7	1·53 × ·64	·979	27·00	27·5	1·09 × ·39	·425	56	„	34	As received from mill.
27	H 7	1·54 × ·63	·970	26·00	26·8	1·09 × ·41	·446	53	„	28	Heated to white heat. Cooled in open air. Temp. 41·2 degs.
28	I 7	1·54 × ·63	·970	26·00	26·8	1·08 × ·43	·464	52	„	29	Heated to white heat. Cooled in open shop.

Chemical Analysis.

No	Mark.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
26	G 7	·18	·03	·06	·06	·54

TABLE III.

? BASIC STEEL, CONDUCTED AT MESSRS. JOHN BROWN & COS.', LIMITED, 1893.

king ain.	At Point of Fracture.		Reduction of Area per Cent.	Elongation.		Treatment.
Tons per Sq. In.	Size.	Area.		In 8 Inches.	Per Cent.	
24·3	1·04 × ·48	·500	63	"	28	As received from mill.
27·7	1·12 × ·48	·538	68	"	12	Heated with heaters 5 min., 70 blows.
23·8	1·06 × ·48	·509	62	"	30	70 blows on anvil (cold).
24·3	1·09 × ·52	·567	57	"	30	" " "
28·6	1·18 × ·55	·649	47	"	13	Heated with heater 5 min., 70 blows.
29·3	1·12 × ·54	·605	53	"	21½	Heated to white heat. Cooled 12 times in water.
23·8	1·07 × ·49	·524	61	"	32	Heated to white heat. Cooled in open shop.
24·3	1·02 × ·46	·469	66	"	33	Left in annealing furnace 48 hours.
24·7	1·15 × ·56	·644	48	"	29	As received from mill.
25·6	1·11 × ·53	·588	54	"	28	Annealed 4 times.
24·3	1·04 × ·47	·489	64	"	31	Left in annealing furnace 4 hours.
24·5	·47 diam.	—	65	"	28	Jumped up to 1¼ in. square (turned test).

7 A; 2, 487 B; and 3, 487 D, were cut crossway of material, all the others being lengthwise

CHEMICAL ANALYSIS.

	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
	·16	·01	·04	·06	·36

TABLE IV.

ADMIRALTY EXPERIMENTAL TESTS, 1881.

Table giving Summary of Tests made for the purpose of finding the effect of Temperature on the Tensile Strain and Ductility of Steel.

No. of Sample.	Description of Steel.	Temperature in Degs. Fah.	Tenacity in Tons per Sq. Inch.	Elongation per Cent.	Remarks.	
1	Bessemer steel plate made by Bolton & Co.	60	28·06	31·25	Elongation taken in 4 inches.	
2		450	38·9	18·75		
3		400	34·3	15·62		
4		460	36·6	14·06		
5		350	40·0	21·87		
6		490	40·8	14·06		
7		490	39·6	18·75		
8		520	42·0	23·43		
9		490	40·8	15·62		
10		630	41·9	25·00		
11		60	26·07	27·34	Elongation taken in 8 inches.	
12		450	40·5	14·06		
13		520	38·7	17·18		
14		880	24·02	26·56		
15	Siemens steel plate made by Bolton & Co.	60	29·10	25·78		
16		below 430	32·9	10·1		Sample defective.
17		below 430	32·3	7·81		" "
18		430	33·45	14·06		
19		490	34·5	18·75		
20		610	28·9	16·4		
21		630	30·6	20·31		
22		630	31·06	17·18		
23		610	27·2	21·09		
24	Bessemer steel plate made by John Brown & Co.	60	28·49	21·87		
25		430	38·4	18·75		
26		550	33·08	17·18		
27		880	18·56	25·00		

TABLE V.

ADMIRALTY TESTS, 1881.

l by the Bolton Iron and Steel Co., and cut into strips, then tested with the following results. Test pieces, 16 inches by 2 inches.

	Results.	
	Tons per Square Inch.	Percentage of Elongation in 8 Inches.
rmal state	29·10	25·78
Tin melted freely on sample, but not lead; no perceptible colour on s below 430 degs. This sample broke in small defects	32·9	10·1
in melted on the sample, no perceptible colour on fracture. Temperature ple also broke in slight defect	32·3	7·81
Tin melted on the sample; broke without colour on fracture or below	33·45	14·06
in melted freely on the fracture, which by colour was 490 degs. ...	34·5	18·75
inc melting freely on the sample, and when broken lead melted on the colour of fracture, 610 degs.	28·9	16·40
same temperature, lead melting on the fracture. Temperature by colour	30·6	20·31
t perceptible in the dark. Zinc melting freely on the sample, and when fracture. Temperature by colour of fracture, 630 degs.	31·06	17·18
at, when broken all the colour was gone, but lead melted freely on the colour of fracture, 610 degs.	27·2	21·09

TABLE VI.—ADMIRALTY TESTS, 1881.

Table showing result of Tensile and Elongation Tests of Steel and Iron after various modes of treatment.

Class of Material Tested.	No. 1. Normal Condition.			No. 2. Sample heated 3 times.			No. 3. Sample heated 8 times.			No. 4. Sample heated 12 times.			No. 5. Sample heated 20 times.		
	No. of Sample.	Tensile Strain per square inch in Tons.	Percentage of Elongation in 8 inches.	No.	Tensile Strain per square inch in Tons.	Percentage of Elongation in 8 inches.	No.	Tensile Strain per square inch in Tons.	Percentage of Elongation in 8 inches.	No.	Tensile Strain per square inch in Tons.	Percentage of Elongation in 8 inches.	No.	Tensile Strain per square inch in Tons.	Percentage of Elongation in 8 inches.
No. 246. Siemens or open-hearth steel.	1	L 31·15	26·56	13	L 31·06	27·34	33	L 30·45	28·90	57	L 29·86	26·56	81	L 31·18	26·56
⅜ in. boiler plate.	2	A 31·16	22·65	14	L 30·65	28·90	34	L 30·58	26·56	58	L 30·64	29·68	82	L 30·14	26·56
High strain.				15	A 30·66	25·78	35	A 30·89	25·78	59	A 31·06	22·65	83	A 30·72	23·43
				16	A 30·85	24·21	36	A 30·39	22·65	60	A 30·92	22·65	84	A 30·96	23·43
No. 378. Siemens or open-hearth steel.	3	L 26·72	28·90	17	L 27·11	29·68	37	L 26·93	29·68	61	L 27·76	28·90	85	L 26·81	30·46
⅜ in. boiler plate.	4	A 26·29	23·43	18	L 27·91	27·34	38	L 27·28	26·56	62	L 27·22	32·81	86	L 26·69	29·68
Low strain.				19	A 26·94	22·65	39	A 27·07	26·56	63	A 27·22	25·00	87	A 27·44	28·90
				20	A 26·94	21·09	40	A 27·25	25·78	64	A 26·71	25·78	88	A 26·96	25·00

Class of Material Tested.	No. 6. Sample heated 40 times.			No. 7. Sample heated 60 times.			No. 8. Sample placed in flue of a stationary boiler 16 days.			No. 9. Sample placed in smoke box of locomotive 16 days.			No. 10. Sample placed in annealing furnace 16 days.		
No. 246. Siemens or open-hearth steel.	105	L 30·44	25·78	129	L 31·10	29·68	153	L 31·11	29·68	173	L 30·25	28·12	197	L 25·42	27·34
⅜ in. boiler plate.	106	L 30·62	28·90	130	L 31·61	32·03	154	L 30·41	29·68	174	L 29·81	28·12	198	L 27·39	29·68
High strain.	107	A 31·03	23·43	131	A 31·55	23·43	155	A 30·60	24·21	175	A 29·97	25·78	199	A 25·87	28·90
	108	A 30·90	25·78	132	A 31·50	22·65	156	A 30·78	22·65	176	A 30·01	22·65	200	A 25·73	28·12
No. 378. Siemens or open-hearth steel.	109	L 26·37	30·46	133	L 26·60	29·68	Not sufficient of the plate to make this test.			177	L 26·36	29·68	201	L 21·60	26·56
⅜ in. boiler plate.	110	L 26·68	29·68	134	L 26·78	33·59				178	L 25·47	26·56	202	L 21·42	18·75
Low strain.	111	A 26·94	26·56	135	A 26·40	25·78				179	A 25·59	26·56	203	A 22·61	26·56
	112	A 26·84	25·78	136	A 26·43	26·56				180	A 25·64	27·34	204	A 22·57	21·87

L = length. A = across.

DISCUSSION.

Mr. G. W. SIVEWRIGHT complimented Mr. Nodder upon the concise manner in which his paper was written, and although it was not a lengthy one, yet the large number of tests made the paper valuable for reference, and it seemed a pity with so many steel-makers in our midst that more papers of this description were not read before the Institution. It was evident from an examination of the chemical analysis of the test pieces and from the results obtained that the steel was of a superior quality; indeed, if the phosphorus and sulphur had been eliminated the steel would have been practically perfect. If it were possible to get the two latter ingredients out of the steel he thought that several of the tests would have been materially altered, more especially, when work had been put upon it in a partly heated condition. He was not aware that shipbuilders and engineers, as a rule, had objected so much to high tensile steel, but what they had noticed was that the failures of steel were more in evidence in high tensile than in low tensile steel, and probably Mr. Nodder, as an experienced steel-maker, would possibly enlighten them on this point. An eminent steel-maker a short time ago stated that the vibration which was supposed to exist in one of the latest fast Atlantic liners would have been prevented if the steel had been of 60 tons tensile, but he (Mr. Sivewright) thought that this vibration in the sister ship had been overcome by simply altering the propellers. On the second page of the paper the writer inferred that the flanging test was not of much importance, but, if the tensile test was of any consequence at all, he (Mr. Sivewright) thought that the flanging test, which was another

annealing. He noticed in the paper that steel of Siemens manufacture may be hammered and bent cold without detriment. He was glad to have a steel-maker of Mr. Nodder's experience state so definitely that this was the case, as one of the greatest objections from certain interested parties was that cold flanging, as practised in shipyards, would set up such a stress in the material that the steel would be unreliable. He (Mr. Sivewright) had cold flanged steel in every possible way and in very large quantities, and in actual use flanged plates pitted against any other form of riveted work had stood the test very satisfactorily.

Mr. T. WESTGARTH thought the testing of steel plates was a great bugbear to boilermakers and shipbuilders, because if a plate was sent in which would not stand the work required to be put upon it the steel-maker at once turned up a copy of his tests and asserted that the plate was perfect, and the fault must lie with the treatment which it had received. His opinion was that the best of all tests was the manner in which the plate stood the work to be put upon it, and he considered that it should be the business of steel-makers who sold plates for ship and for boiler work to provide material which would stand the ordinary methods of manipulation. He agreed with Mr. Sivewright that by careful manipulation of test pieces almost any result could be attained. It so happened that when the speaker was a junior he had to make a great many tests in the early days of steel, and he soon found out how to get good results. Another difficulty which he hoped would be discussed, was the question of using heaters for closing plates. With the best workmanship it was sometimes necessary to close joints, etc., and foremen and workmen always insisted that this could not be done without heaters, and they declared that it was often quite impracticable to close a place without first applying heaters. He hoped that some of the practical members of the Institution would give their experience upon this important matter.

The PRESIDENT did not think the meeting should be under the impression that, because certain questions were raised about steel, there was a danger of setting people against its use. That would apply equally well to iron. As a shipbuilder he quite agreed with what Mr. Westgarth had said as to the result of the working of material being the best criterion of its quality ; any defects were generally found in the punching and bending of plates. He had seen an iron plate thrown off a lorry, on to a stone pavement, picked up in two pieces. He had a steel oxter plate put on a ship overnight, a keen frost set in, and in the morning they found the

plate cracked all through. That plate had not been annealed, but simply punched. He kept the plate in the yard for the benefit of those gentlemen interested, and sent it back to the steel-makers, but they held that they were not responsible for a plate after delivery. He was now keeping a record of such cases. It was rather a curious circumstance that when they first commenced using Siemens-Martin steel they had not a failure over a considerable period, but within the last few years, in bending plates cold, they had had several failures, What was the cause of these failures he could not explain, but it seemed rather curious that when steel first came in there were no failures reported, while within the last two or three years they had frequently occurred.

Mr. WESTGARTH—You say you have had trouble now in cold flanging —did you cold flange them at first?

The PRESIDENT—No; they were bent in the way usual to iron plates, but for some years now all their steel plates were flanged by a hydraulic bending machine.

Mr. R. WOTHERSPOON thought they would be all agreed that a more important subject than that introduced by Mr. Nodder could not be brought before them. The subject of steel had exercised and often perplexed the minds of engineers far more than ever it had shipbuilders, as the department of engineers led them to see that the boilers were properly constructed, and the material properly manipulated in the yard. Mr. Nodder in his paper had stated that "The results of a long series of tests would teach that the heating and reheating of Siemens steel made little

and heated in the same furnace, and rolled into a similar plate. In slab form it had ·12 per cent. carbon, and ·024 per cent. sulphur, and in the finished plate had ·17 per cent. carbon, and ·048 per cent. sulphur. It was proved from these results that the steel had absorbed both carbon and sulphur (the latter to a large extent) during the process of heating, the sulphur tending to make it hot short, and the carbon tending to make it brittle. Mr. Westgarth had spoken of the failure of plates in boiler shops, but if they considered the treatment which a plate over 1 inch in thickness receives in the operation of hand flanging the cause of many failures would not be difficult to find out, more especially when they considered the fact that the failure of plates during the operation of flanging was practically unknown where they are not overheated, and where efficient flanging machinery is employed, and the plates properly annealed. But if they left the important question of treatment to the one side and consider the element of fire there is something in this well worth investigating.

Mr. SIVEWRIGHT said they were given to understand by the manufacturers of steel that it was difficult to get the sulphur out of it, and he thought it would be equally difficult to get it in again.

Mr. WOTHERSPOON said he could give Mr. Sivewright the analysis of the steel before being heated at all, it was when heated to some extent like a sponge.

Mr. A. MCGLASHAN said, from observation of many hundreds of tons of steel used in shipbuilding he had seen no signs of the quality deteriorating in late years. It showed itself at least equal to the steel of former years. He remembered, about fourteen years ago, on a very large ship about ready for launching that a boss plate was fixed and in course of being riveted. During the dinner hour something happened with it, for when the riveters came back to it they found on close examination that is was fractured over the greater extent of its surface, with scarcely a part, the size of one's hand, that had not fractures in it. He remembered, too, that from then down till after the time when steel was introduced on this coast for building cargo vessels a large number of failures took place in the manipulation of plates, and surveyors and others who had a knowledge of the properties of steel, derived, no doubt, from such tests as those referred to in the paper, pointed out to foremen and others the great danger of working steel at what was called a blue heat. He believed an acquaintance with that danger had done a great deal to reduce the

number of failures of plates. In fact, ship after ship was built, in ordinary circumstances, without a single failure occurring. Sometimes a plate would break in cold flanging, but with an easy radius on the bearing surface of the flanging machine they scarcely ever had a failure. He mentioned these facts as being interesting from a practical point of view.

The discussion stood adjourned.

The PRESIDENT expressed his pleasure at the usual large attendance and the excellent discussions they always had when meeting at West Hartlepool.

The meeting then dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINÉERS AND SHIPBUILDERS.

TENTH SESSION, 1893-94.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, SUNDERLAND, ON WEDNESDAY EVENING, DECEMBER 20TH, 1893.

ROBERT THOMPSON. ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in West Hartlepool, on Saturday, November 25th, 1893, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. R. Fothergill and H. Macoll to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Egan, James, E. Draughtsman, Young Street, West Hartlepool.
Dixon, James, Marine Draughtsman, Wincomblee, Walker-on-Tyne.
Hepple, William Thos., Engineering Manager, Messrs. Hepple & Co., Engineers, Wapping Street, South Shields.
Kelsey, William, Engineer, 4, Lily Avenue, Jesmond, Newcastle-on-Tyne.
Meldrum, Michael, Supt. Engineer, 2, Belle Vue Crescent, Sunderland.
Wait, Thos. Herbert, Consulting Engineer, Cail's Buildings, Quayside, Newcastle-on-Tyne.
Walton, Samuel, Inspecting Engineer, 34, Pollard Street, South Shields.
Ward, Mark M., Engineer, 76, Church Street, West Hartlepool.
Wimble, Arthur, E. Draughtsman, c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne.
Wood, Henry Alfred, Chief Ship Draughtsman, c/o Messrs. W. Pickersgill & Sons, Sunderland.

GRADUATES.

Beilby, Norman Harry, Apprentice Engineer, 27, Eldon Square, Newcastle-on-Tyne.

Bertram, Robt. Thompson, Apprentice Engineer, 41, Clayton Park Square, Newcastle-on-Tyne.

Cowell, Richard E., Apprentice Engineer, Montpellier, Sunderland.

Pearce, Standen L., Apprentice Engineer, 42, Milton Street, West Hartlepool.

Raincock, Walter, Apprentice Naval Architect, 8, Washington Terrace, North Shields.

Robinson, Charles O., Apprentice Engineer, Ingleside, North Shields.

Simpson, Kenneth, Ship Draughtsman, 33, North View, Heaton, Newcastle-on-Tyne.

Smith, William S., Ship Draughtsman, West Villa, The Green, Wallsend-on-Tyne.

Thomas, Harold, Ship Draughtsman, 1, Nelson Terrace, Stockton-on-Tees.

The discussion on Mr. W. Hök's paper "On a Method of Comparing Steamship Performances and of Estimating Powers and Speeds of Ships" was resumed.

The discussion on Mr. J. Nodder's paper on "The Dangerous Working Heat of Mild Steel and the Effect of Annealing and Air Cooling" was concluded.

Mr. Frank Caws read a paper "On certain Principles of Motion, as taught by the Pendulum; and as illustrated by the Resistance of Ships and other Bodies moving through Fluids; together with a brief sketch

ADJOURNED DISCUSSION ON MR. W. HÖK'S PAPER "ON A METHOD OF COMPARING STEAMSHIP PERFORMANCES AND OF ESTIMATING POWERS AND SPEEDS OF SHIPS."

Mr. JAMES PATTERSON said he had devoted what spare time he had had at his disposal to an examination of this paper. There was a great deal of matter in it, and it took a great deal of examination. He had found it impossible to go into the whole of the details. The paper divided itself naturally into two parts: there was the method of recording data, and there were the conclusions drawn on different subjects upon which the method of analysis was supposed to throw light. He would take them in the reverse order, as he thought the conclusions would throw a great deal of light upon the method. The first one to which he would direct their attention was the one with regard to triple screws. Mr. Hök here took the case of the steamer "Tripoli." He said that when driven by two of her screws the efficiency was about the same as when all three were in use, but when driven by one only the result was much inferior; therefore single screw propulsion was inferior to twin-screw or triple-screw propulsion. Now, that was simply a confusion of ideas. The vessel was designed for three screws, and presumably the three screws were proportioned for the work they had to do, in which case the one screw would, roughly speaking, be about one-third what it should be as a single screw, and they could not expect efficiency from a propeller one-third the proper size for its work. The confusion of ideas was so apparent in this conclusion that it was hardly necessary to point it out, but he brought it forward because in each of the conclusions he had examined in this paper he found a similar, though less evident, confusion of ideas. Rather than taking them in order, he would refer to one of the most important, viz., to the paragraph where Mr. Hök compared transatlantic liners with Government cruisers, and advocated strongly a form of ship of the "Edgar" or "Blenheim" type, as their "performance was unapproached by anything in the mercantile marine," and then speculates on "what changes in the building rules would make it profitable, and what alterations to docks, harbours, and rivers would make it possible" to adopt that form. To commence with, Mr. Hök in his conclusion begs the question, for undoubtedly before pronouncing in favour of any one form rather than another for the transatlantic service, many things would need consideration, such as relative weight of hull and deadweight,

total coal consumed and to be carried, relative performance in a sea-way (which is very different from a smooth water trial trip), and other things. But pass this over and accept Mr. Hök's basis of comparison, viz., I.H.P. per ton of displacement at given speed in smooth water, and see to what it leads. Take the "City of Paris" form, No. 32 ship, to represent the transatlantic liners, and the "Blenheim" form to represent the Admiralty design. Referring to Diagram No. 9, Plate IX., it is seen that 9 knots is a suitable speed at which to make the comparison, being nearly full speed for No. 32 ship. At that speed the I.H.P. required per ton for No. 32 is ·71. Now, another ship of the same form but of double the size, that is double the displacement, will by no means require double the horse-power to drive it the same speed (this is of course well known from the laws of propulsion, and proof here is unnecessary), therefore, as it is form we have under consideration, and as for the same form and same speed the horse-power per ton of displacement varies with the size we must fix the displacement at which that variable is to be taken as the measure of performance, otherwise its value may be anything we like to make it. Take, therefore, the "City of Paris" form at the size of No. 32 model, viz., 79·8 tons. The I.H.P. required to drive this model 9 knots is between 56 and 57. A ship of the same size of the "Blenheim" form would be about 77 feet long and require between 53 and 54 I.H.P. for the same speed. There is a gain, but nothing like what Mr. Hök argued. If, however, instead of adding largely to the beam and draught, and shortening the "City of Paris" as advocated, we keep the same beam, increase the draught somewhat, and lengthen her, we get a ship of form No. 15, the "Vesuvius," which, on making the calculation, will be found to require at the same displacement only 40 I.H.P. for 9 knots, therefore, at this

compare the one with the other, on the basis of I.H.P. per ton of displacement, they must refer the forms to the same displacement. As to the question of cargo steamers compared with Admiralty design, if Mr. Hök's whole contention was that their present cargo steamers could not be driven economically at high speeds, well, they knew that, nor did he wish to dispute it; but Mr. Hök did not content himself with that, he said that even at the economic speeds of modern cargo steamers, the Admiralty designs (instancing No. 140 and others) were much better. Of modern cargo steamers, on which he was basing this conclusion, there were on the whole list only two steamers of a coefficient of fineness more than ·69, a slender basis to build on, but if representative types no fault can be found on that score, but to compare No. 92 of 143 tons with a steamer No. 140 of 280 tons or thereabouts, they must first go through a long figuring process to reduce the one ship to the same displacement as the other, and see if it would be carried on the same horse-power. He (Mr. Patterson) had not gone through that figuring, but from the look of the curves he thought there would not be much in it; there might be something. In the engine friction matter he did not think Mr. Hök was justified in his conclusion altogether. He (Mr. Patterson) did not say he was wrong, but as far as the paper went he did not think it justified the conclusion that he came to. Other speakers had shown that in some cases the effect due to ratio of wetted surface to displacement had been confused with effect due to excessive engine friction. On another point Mr. Hök instanced the "Umbria" and the "City of Paris" as examples to prove that two engines had more friction in proportion to power than one. The "City of Paris" curve showed greater efficiency at the high powers, and the "Umbria" at the low powers. Now, with nothing in the paper to prove that that was due to engine friction he said that Mr. Hök was not justified in his conclusion. In all probability the "Umbria's" propeller was as large as it could be made on the draught available. He knew of a ship from the same builders for the same company, the "Alaska," with less power and less speed had as big a propeller as they could get in, with the limitation of draught. Therefore the "Umbria's" propeller probably might be slightly small for the higher speeds, and the "City of Paris's" twin-screws would not be limited in such a way, and would therefore give greater efficiency at those speeds but at the lower speeds, probably the "Umbria's" propeller would be the better proportioned and give better results. He did not say it was so, but it might be as far as there was anything in the paper to the contrary. They would see, therefore, he was at issue with Mr. Hök

in the main conclusions and process of making the deductions from the curves on his paper, and he thought that the writer had been led astray by the adoption of an unsuitable basis of comparison, not but that anybody might choose displacement, *per se*, as a basis of comparison ; but it was necessary in making deductions to remember that this basis had been taken. Mr. Froude used displacement (with an appropriate index), but recognised that it was his basis of comparison, and laid down the speeds as the sixth root of the displacement, not as the square root of the length of the ship, and in that way he eliminated size, and could compare directly on the same ordinate one ship with another for any given speed. Another advantage was gained by taking $D^{\frac{2}{3}}$ instead of the displacement itself, because in similar ships $D^{\frac{2}{3}}$ was an exact measure of the wetted surface, and therefore for low speeds measure of the resistance, and for dissimilar forms it still approximately measured the wetted surface. In the case of shallow ships, of course, they would find that there was far more wetted surface per ton of displacement than there was in deep ships, and that, of course, would make their curves show that the shallow ships were less efficient than the others, and they were so, as Mr. Hök contended, but the curves he plotted of I.H.P. per ton of displacement gave no reason for this, and one was apt to apply the reason to some other cause, as Mr. Hök had done in his paper. To turn now from destructive to constructive criticism, he believed that if they wanted to record trial data for the general purposes of the naval architect he would be a very good man who would improve upon Mr. Froude's method. It was a very comprehensive, a very good method. On the other hand, an engineer did not want to deal with all the problems of the naval architect. The engineer's problem was this : given a certain size of ship of given propor-

that, and how much for wave-making resistance, to deal with which separately, guided by the angles of the entrance and run of the ship, would be much easier than if mixed up with the resistance of the wetted surface. By that means he thought the engineer would get a very much simpler formula, which would be absolutely accurate for similar ships, and much more nearly accurate for dissimilar ones than Mr. Hök's method of using I.H.P. per ton of displacement for the measure.

Mr. GEO. N. ARNISON, Jun., said that without having considered Mr. Hök's paper as fully as the previous speaker, yet some of the conclusions given in the "Analysis of Trial Data and Comparison of Steamship Performances," on pages 29, etc., had specially attracted his attention. Amongst the number was the fifth, which was entitled "Single Screw *versus* Twin Screws." Here Mr. Hök said "A glance at Diagrams 4, 5, 6, and 7 shows conclusively that, generally speaking, *twin-screws are superior to the single screw.*" He (Mr. Arnison) thought it would have been better if "generally speaking" had been further explained. Anyone might almost come to the conclusion that Mr. Hök considered in an ordinary screw collier twin-screws would be more efficient than a single screw. Possibly Mr. Hök would in his reply state whether that was his opinion. Probably, however, he meant that in vessels having powerful engines, *e.g.*, of 10,000 I.H.P. and upwards, twin-screws were more efficient than single screws, and also in the case of steamers which had to trade in a very shallow draught of water. Again, in the paragraph entitled "Paddle Wheels," Mr. Hök states they "appear less efficient than screws. However, their inefficiency is purely chimerical, and is due to the shallow draught and its accompanying increase of resistance." This conclusion had already been referred to by the previous speaker (Mr. Patterson), who apparently was of opinion that the inefficiency was due to the shallowness of the vessel necessitating a relatively great wetted surface. He (Mr. Arnison) thought on reflection Mr. Patterson would remember that when shallow vessels were in shallow waters there was increased resistance.

Mr. PATTERSON—You should have the deep-water trials.

Mr. ARNISON—No doubt; but some of the results in the paper may be those obtained under the ordinary circumstances of the vessel's steaming in shallow waters. However, the general remark that excessive wetted surface explained the inefficiency of paddle wheel steamers was not in his (Mr. Arnison's) opinion completely satisfactory.

Although it seems to me that Mr. Hök's method is not more accurate, but certainly more complicated, than such methods as those by Mr. J. Inglis and Prof. Biles, I will not by any means detract from its value but add my testimony as to its high merit among the papers in the *Transactions*.

Yours faithfully,

J. JOHNSON.

SUNDERLAND,

DEAR MR. DUCKITT, *December* 19*th*, 1893.

The Admiralty method of comparing vessels is somewhat similar to that suggested by Mr. Hök in his paper, except that in their case the form alone is compared; all vessels being reduced to a common basis with a curve of sectional areas appended, the differences being then easily and accurately ascribed to their true source.

On the other hand, the method before the Institution can only result in perpetuating the errors of the past. This appears when you consider that the efficiency of the propeller, *the most vital element in the combination*, is left untouched.

The Atlantic steamers are probably the most inefficient type of vessel running, principally on this ground, as is shown by Mr. Hök's graphic curves. More particularly is this evident when the question is asked if the "Edgar" type should not become the Atlantic liner of the future?

On stability, unsinkability, and speed grounds alone, one is led to the belief that this is imperative, whilst on commercial grounds it seems also more desirable.

What registry societies will do in that event can hardly be predicted,

efficiency of the screws. This warrants the assertion that the dimensions of the present Atlantic liners call for a considerably higher speed than that yet attained.

If, however, quicker running machinery be practicable, and there seems no reason otherwise, more satisfactory results will obtain. This is important in view of the celebrated "Iris" trials, although many other ships have had the same history, where small screws obtained higher speeds under similar conditions with the same power.

How, then, can any method, which bases its existence on results so obviously remote from perfection, be accepted by a learned society?

In reference to cargo steamers the method of the author will be found of value, since the propeller element need not be considered. Comparing high speed vessels with cargo steamers it will be found that at the speeds common to the latter class current practice, although very variable, secures satisfactory results.

In short, up to 11 knots almost any propeller in practice, on any type of ship, gives practically equal values, and need therefore not be considered.

Generally, seeing that so many variable factors obtain in current practice which require either accurate estimating or preferably eliminating, no method which merely accepts the facts, without the assurance that such are reliable and incapable of improvement, ought to be accepted.

To my mind any progress in the future will come from the machinery department, as the form of ships, other than cargo steamers, leave nothing to be desired.

Unfortunately, my experience teaches me to appreciate the difficulties of the subject, and only permits me to say how difficult the framing of any such formula is. It is because the basis of Mr. Hök's method is to me so insecure that I am sorry to find myself at variance with him. His efforts I thoroughly appreciate, and think his collection of data very commendable, and deserves the thanks of the Institution. However, I am satisfied that rather than accept results as final, which are capable of very great improvement, it would be wiser to advocate the introduction of an experimental tank into the district, in which models of both ships and screws should undergo a series of scientific experimental trials.

This will be found the best and surest, I was almost going to say the only method.

Yours faithfully,

J. J. O'NEILL.

PORT GLASGOW,

DEAR MR. DUCKITT, *December* 18*th*, 1893.

I have read with much interest the proof Mr. Hök kindly sent me of his elaborate and exhaustive paper. The very fulness of the paper to some extent militates against the discussion of it, so many lines of thought opening up to prevent concentration of thought on any particular one. So far as possible I will confine myself to some of Mr. Hök's inferences and conclusions.

His remarks regarding engine friction are particularly valuable, and show clearly how unsafe it is, even when we possess progressive speed data to use them for estimating purposes without very great discrimination; for instance, if it is found by experiment that a steamer 300 feet long required 1,400 I.H.P. to drive her 11 knots when she has engines designed for driving her 13 knots, it will not be the case (speaking generally) that another identical steamer will require 1,400 I.H.P. to drive her 11 knots when she has engines designed for 11 knots. Mr. Hök's method of applying the necessary correction is a bold attempt to get over the difficulty, though it can only be regarded as a rough and ready one. The typical curve of propulsive coefficients, reduced as Mr. Hök reduces them, being, so far as my experience goes, rather as curve D (see Plate XIII.) than as the curves A, B, and C which he gives. If experimental tanks were more abundant (and we shipbuilders may well wish they were) there is no doubt that these variations of propulsive coefficient would give an early and very important line of investigation. To myself they form a chief reason why when I can get model experiments to estimate from I greatly prefer them to ship results, because I can then supply the propulsive coefficient which seems

it is not very remarkable that those of curve 50 (to take one instance), which are to be expected at 6·1 knots and 6·9 knots, are faint enough to be masked by unavoidable irregularities, and that that only at 8·1 knots becomes prominent. The table, I think, requires very great revision in other respects; very little, I believe, is ever gained by a finer block coefficient than ·45 to ·4, and the reason why yachts are sometimes made finer is that while length, breadth, and draught cannot for various reasons be reduced, the displacement is determined independently and kept as little as possible; at high speeds, however, lines are everything, and especially should careful attention be paid to prismatic coefficient; many a yacht would be improved by having a fuller section and finer lines.

I understand Mr. Hök's referring power to displacement instead of $(\text{displacement})^{\frac{2}{3}}$ has been a good deal criticised, amongst others by Mr. Froude. One effect of his so referring, it may be pointed out, viz.:—Mr. Hök's conclusion that it takes somewhat more power per ton of displacement to drive vessels of small displacement than vessels of large displacement. This is a well-known fact, and is simply expressed in other words by saying that power is more nearly proportional to $(\text{displacement})^{\frac{2}{3}}$ than to displacement, it being of course assumed that length, fineness, and speed are the same for the cases compared.

Yours faithfully,

F. P. Purvis.

Mr. Hök's reply was postponed till the following meeting.

DISCUSSION ON MR. JOSEPH NODDER'S PAPER ON "THE DANGEROUS WORKING HEAT OF MILD STEEL, AND THE EFFECT OF ANNEALING AND AIR COOLING."

Mr. J. R. FOTHERGILL resumed the discussion on Mr. Nodder's paper. He said that first of all he desired to thank Mr. Nodder for his very able paper, and he felt sure it was one that would enhance the value of their *Transactions*. He thought those who had read the paper would agree with him that it was a paper very difficult to discuss, because it was principally a record of facts and experimental data. A paper more suitable to the criticism of a steel manufacturer than a marine engineer, yet there were one or two questions in which he ventured to disagree with Mr. Nodder. In the second paragraph in the paper Mr. Nodder said :—"The distinction between high and low tensiles within the limits of 26 to 30 tons was a fallacy." He agreed with Mr. Nodder that in speaking of steel generally as used for all sorts of purposes he was no doubt correct, but when referring to steel used in the manufacture of marine boilers and furnaces in particular it was altogether another matter. The Board of Trade and Lloyd's limited the tensiles between 26 and 30 tons as a minimum and maximum range, and therefore he contended marine engineers were perfectly within their right, and justified in using the expression "high and low" tensiles. In the same paragraph Mr. Nodder states :—"Steel of 26 tons tensile or 30 tons tensile can be produced from the same ingot almost at the will of the plate-roller, certainly without any variation of the chemical constituents of the materials." This was a well recognised fact, but what he (Mr. Fothergill) contended was that when the tensile of steel in manufacture was increased without variation of the chemical constituents the effect was "mechanical," viz., the material was in a condition of "mechanical stress," and such condition would be, as Mr. Nodder over and over again stated in his paper, overcome, and the material resume its normal state by annealing. This appeared to him to raise a very important question as to the true definition of tensile. Were they justified in accepting the tensile prior to annealing? Was not the correct or true tensile of the material the tensile after annealing? Supposed they rolled two plates from two ingots identically similar in their chemical constituents, and both plates rolled to exactly the same thickness, say ½ inch. Assume one plate to be rushed through the rolls quickly, giving a tensile of, say 26 tons; the other plate, due to more work being put upon it, and a much

longer time taken in rolling, would show a tensile of, say, 30 tons. He would ask Mr. Nodder if he considered it fair and reasonable that the tensiles of these plates should be given as 26 and 30 tons when, as a matter of fact, if both plates were annealed the tensile in both cases would be practically the same? Was it not a fact the Admiralty required the tensile from all boiler plates to be taken after annealing? There was another question he would like to ask Mr. Nodder. Suppose two furnaces were manufactured—the one of 26 tons steel and the other of 30 tons, and that these tensiles were the tensiles of annealed plates, viz., the tensiles from plates that had been annealed after manufacture. Assume, due to some unfortunate circumstances, these furnaces when in use became overheated and came down. Will Mr. Nodder say if, in his opinion, one furnace would be more liable to crack than the other, and, if so, whether he did not believe the 30 tons furnace would be more liable to crack than the 26 tons? Mr. Nodder had very properly remarked on the effects of air cooling, and shown that a plate could be heated to 1,100 degs., and cooled off on a railway siding without serious effect, and after giving other illustrations concludes :—"The whole results clearly prove that air cooling, even under extreme variations of temperature, can make no appreciable difference to this class of material." These results in themselves were remarkable, but what he (Mr. Fothergill) contended was that if a hot plate happened to be placed in a position exposed to a draught, and all boiler shops were not free from draughts, and that the draught caught one portion of the plate only it would locally chill it, with possible ultimate cracking. He was very pleased to see Mr. Nodder's strong condemnation of local

note, could be counted on one's ten fingers. Of all these failures, as far as we can find, only two have occurred which could be traced even remotely to this cause. Both of these were boss plates, on which a large amount of work had to be done. In both cases they were badly fitted, and more work had to be done on them when in place, then they developed cracks. It would thus appear, from practical experience in a shipyard, that the danger is infinitesimal, and that, taken as a whole, open-hearth steel is a thoroughly reliable material.

In regard to basic steel, our experience has not been so happy; it is but right, however, to say that this was in the early days of the material and before the exhaustive series of tests was made by Lloyd's surveyors at the Glasgow Steel Works. We purchased a lot of basic steel frame material which, in the usual tensile and bending tests, gave magnificent results, but in punching the frames, several of them developed cracks and showed cold shortness. Samples taken in way of the fractures and tested for tensile and bending gave again splendid results. The trouble we had in this material was such that we have never since ventured to use it knowingly.

Yours faithfully,

A. DENNY.

MR. NODDER'S REPLY.

Mr. J. NODDER, in reply to the discussion, said that it appeared his most serious opponent was their friend, Mr. Fothergill. At Hartlepool very little was said that really condemned the thoughts of the paper. There was one remark made by Mr. Wotherspoon with reference to some annealing that he had been interested in, in which he said that a steel slab was cut in halves and heated, but one was covered with duff coal, and had ·13 per cent. of carbon, whereas the other half had only ·12 per cent. He could hardly give an opinion as to the relative proportions of carbon and sulphur without he had the actual data of the heat at which this plate had been dealt with. The final result Mr. Wotherspoon seemed to think was that the plate had appropriated ·024 per cent. of sulphur during the process of annealing, and ·05 per cent. of carbon. That was not his experience of annealing. He had not submitted it to the same process of covering it with duff coal, but he should expect to have to raise the plate to a considerable heat before he could make it appropriate either carbon or sulphur. If they would look at Table I., page 72, they would see that he introduced these chemical results, not because he was a chemist, far from it, but because he thought it might interest some of those who questioned the chemical construction of the steel. If they

looked in Table I. they would find that several test pieces out of the same plate had been subjected to various treatments, amongst others one piece was left in the annealing furnace four hours. His experience was that it did not take up any sulphur, in fact it was not altered in its chemical constituents in the least, so he thought Mr. Wotherspoon's analysis would have to be in greater detail to explain why the steel took up $\frac{2}{100}$ths of sulphur, yet even the final results he should consider very good in its proportions of sulphur and carbon. Mr. Fothergill objected to his view of the expressions "low tensile" and "high tensile." He (Mr. Nodder) simply put it in that form because high tensile steel to him was something like 50 tons to the square inch, and low tensile was anywhere between 24 and 30 tons, or as the Board of Trade and Lloyd's put it, between 26 and 30 tons. The question of annealing by the Admiralty, which Mr. Fothergill referred to, was not asked for by them. He might say the Board of Trade and Lloyd's insisted upon taking their tests from the plates exactly as they were rolled. With the Admiralty it had been the custom always to anneal, and the tests had been taken as annealed test pieces. In the discussion at Hartlepool Mr. Westgarth expressed himself that in his experience in the testing room he was able to do pretty much what he liked with his test pieces. He thought that was perhaps applicable to the question of annealing. Personally, he said the test should be taken from the plate as rolled at the mill. Respecting the question of heating and cooling, Mr. Fothergill rather differed from him. His (Mr. Nodder's) experience had been that so long as a plate was evenly cooled in the air it did not matter very much what the temperature was. He did not suppose it would be the correct thing if he had some furnaces to cool that he should take them out of the annealing furnace, and put them in an

ment of facts to hit home, and if they did not conform with the experience of boilermakers, then he should have met their opposition and been able to deal with it. But that had not been the result of the paper. During the last month certain things had happened which perhaps it would be well to speak about. At a firm (not in that district) there were a number of furnaces of the Purves type, the tube plate was made hot and put on to the cool furnace and hammered up to it, and the furnace hammered up to the tube plate, and in that condition it was found that several of these furnaces cracked at the corners of the return flange, and to his mind it was an exact reproduction of the experiments of his paper—it was putting a heater on purely and simply, and those furnaces required to be annealed afterwards before they were in a fit condition for use. They were made brittle. He also promised at the last meeting, in deference to a note he had received from Mr. Milton, to experiment on some low tensile Siemens steel, that was Admiralty tensile. He had not been able to get exceedingly low tensile, such as was talked about; 22 tons tensile seemed hard to get at, but he tested some of 24 tons, and the results were practically the same as the higher tensiles. He was also asked how many blows it was necessary to give, that was, what was the minimum number of blows that would affect the steel. He found it affected from five blows and upwards. He had also taken a piece of steel in the same form and put it over the swage block with half-inch hollow and gave what they might call a bending blow. He had found that that was perhaps slightly more destructive than the actual flat blow on an anvil, but the difference was not very great. In deference to another person's judgment he also took some best Yorkshire iron and he had got some of the worst results possible out of it. He had found that the commoner irons made not so serious a break, but in the case of the best Yorkshire iron, as received from the mill, it gave 22 tons per square inch with an elongation in 8 inches of 18 per cent. At five blows that elongation was reduced to 16 per cent.; at twenty-five blows it was reduced to 4 per cent.; at fifty blows it was practically *nil*, it broke exactly like a carrot under the testing machine. These, he might say, were bending blows. With flat blows on an anvil he got a worse result from the smaller number of blows: where he got 16 per cent. elongation at five bending blows, he only got 10 per cent. at flat blows. He would say that all test pieces were cut out of one plate. With a low tensile Siemens steel the result came out much more rapidly. He got the reduction from 29 per cent. elongation down to 18 per cent. with only five blows. So it showed how very delicate—if he might use the word,

with due deference to engineering friends—Siemens steel was, in fact so delicate that it should, perhaps, be wrapped up in cotton wool. Now, this was entirely removed by annealing, and then they could do what they liked with it, but when they remembered that the ordinary practice of the shipbuilder was to treat it exactly as he had done iron in the old days and thought it would stand; it certainly would not, and that was all he could say about it. There was a reference made at the Hartlepool meeting as to whether steel to-day was as good as it used to be. In his judgment it was better. That might be open to question by someone else, but that was his experience. They got better Siemens steel now than formerly, and they could do more with it either hot or cold.

The PRESIDENT said he was sure it would be their pleasure that a hearty vote of thanks be given to Mr. Nodder for the paper he had read and the reply he had given. He was quite sure that the statistics of the tests of steel would be a very valuable addition to the library of the Institution.

The vote was accorded by acclamation.

ON CERTAIN PRINCIPLES OF MOTION, AS TAUGHT BY THE PENDULUM; AND AS ILLUSTRATED BY THE RESISTANCE OF SHIPS, AND OTHER BODIES MOVING THROUGH FLUIDS; TOGETHER WITH A BRIEF SKETCH OF THE PENDULUM SPEED-POWER METER.

By FRANK CAWS.

[READ BEFORE THE INSTITUTION, IN SUNDERLAND, ON TUESDAY, DECEMBER 20TH, 1893.

Numerous and able writers have told us exactly what are the laws governing pendulum oscillations on a world where there is no air, nor other resisting medium, nor obstacle to motion.

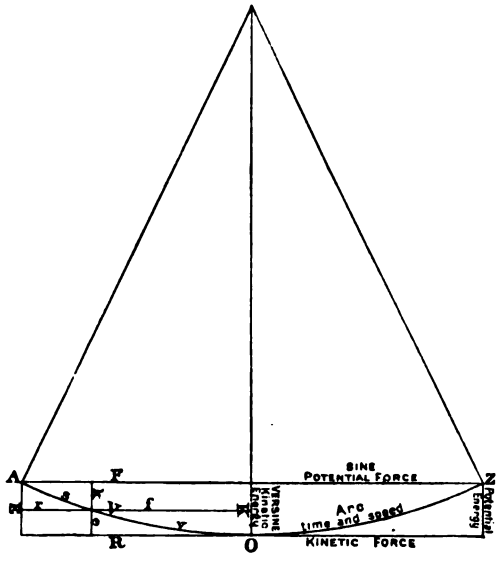


FIG. 1.—UNRESISTED MOTION.

Amongst other things, they tell us if the bob be allowed to start at A (Fig. 1) it will swing over to Z; and, as Z is on the same level as A, the bob will return from Z right back up to A; and this to and fro motion, from A to Z and Z to A, will continue perpetually, the bob always passing the vertex at the same speed. That vertex speed is equal

to the velocity attained by a mass in falling through space of the same vertical height as the height of A or Z above O, the only difference being in the direction of the velocity at vertex level; that of the free falling mass being vertical, and that of the pendulum bob being horizontal. But the time taken by the pendulum bob in which to realise its vertex velocity exceeds the time in which the falling free mass descends from the A Z level to the O level, as the length of arc A O, or Z O, exceeds the length of the versine, or vertical dip, of that arc.

We might foolishly discard this doctrine of mathematicians, on the ground that neither in the heavens above nor on the earth beneath is there, or can there be, such absolute immunity from resistance as this doctrine involves or implies.

But we shall more wisely respect the abstract truth thus formulated; regarding it as the upper limit of truth's range, and learning how to apply it correctly to the conditions which impose more or less resistance on all real motion.

There is no instrument so well adapted to teach us the differences between the conditions of unresisted and resisted motion as the pendulum. For we know, as above indicated, exactly what the pendulum would do if unresisted; and, comparing its actual doings with those ideal doings, we observe their differences; and can thus measure the exact degrees which the resisted pendulum falls short of the ideal performances of the unresisted pendulum.

The writer has invented a simple method of measuring, with extremest accuracy, these shortcomings of the real pendulum. A graduated bar, called the "reading bar," is fixed in the vertical plane of the pendulum's motion immediately above the bob. The pendulum strings, being double,

Say, now we clamp the left-hand vernier at A, or 20 degs. (Fig. 1). We now tie back, by a leash line, the pendulum bob, so that the pendulum strings just touch the needle hanging from 20 degs. We then place on the opposite side of vertex the corresponding vernier with its needle. After burning the leash line we discover whether we have placed this final vernier correctly. If we have done so, the pendulum strings, when they swing over, will just touch the needle, causing it to tremble very slightly. If it tremble violently, we know the final vernier was placed too near vertex. If, on the other hand, the needle betray no vibration at all, we know the final vernier was placed too far from vertex. In either case, we alter the position of the final vernier, repeating the experiment again and again, till we get the correct position. Now this position will be more or less short of Z, or 20 degs., according to the amount of resistance encountered. A few tries will succeed in discovering the true position.

When once, in this manner, the exact position of the final needle is found, the experiment may be repeated any number of times, without the slightest irregularity in the behaviour of the pendulum; and thus we prove that experimental results obtained in this manner are as nearly absolute in their accuracy as any experimental results can possibly be.

Let us now, by the aid of this invention, examine the nature of the differences between ideal (unresisted) and real (resisted) motion, as displayed by the actual movements of the pendulum in graphically intelligible form.

The pendulum will serve the dynamician for his purposes in this examination, as the edge of a cliff or chasm serves the geologist; by yielding, as it were, a natural section, which displays causes and consequences in their proper orders, relations, and magnitudes.

Geologists have differed in their interpretations of the teachings of cliffs and chasms. Dynamicians may likewise differ in interpreting the teachings of the resisted pendulum. But the more intent the study in both branches of scientific search, the more nearly will the students arrive at unanimity of interpretation.

The letters of the alphabet, when each considered alone, cannot be said to be expressions of fact. Yet if on that account we would not learn the alphabet we could never learn to read.

Just so, the dynamic principles, or properties, of the unresisted pendulum, as commonly taught in mathematical books and schools, though strictly applicable to no existing state of things, must be understood by the student before he can read aright the phenomena of actual motion,

and realise to the full the greatly impressive fact that the motions of a resisted pendulum are the true type, example, and pattern of all motion in the universe.

For all motion everywhere is, like that of the pendulum, pulsating. And every pulse of motion begins and ends with its purely potential phase, and reaches at midpulse its purely kinetic phase, just as the pendulum does.

That is to say, that at the initial and final moments of each pulse the motion is in full readiness for development; or is, in other words, potential; and at the midmoment, or vertex, of each pulse the motion is fully developed; or is, in other words, kinetic; and at moments intervening between the middle and ends of pulse the motion is partly developed and partly ready for development; or is, in other words, partly potential and partly kinetic.

In all these respects, and in every other dynamic essential, all motion universally agrees, in the character and principle of its throbbing, with the beatings of the pendulum.

Before entering more deeply into this subject, let us distinctly understand that when an unresisted pendulum is starting from any initial angle, the horizontal force potential at that angle, and which the bob will be kinetically exerting when passing vertex, is proportional to the horizontal distance of the bob at the starting angle from the plumb-line. And, as this horizontal distance is the sine of the starting or initial angle, we come to understand that the horizontal force kinetically exerted by the bob at the moment of passing vertex is proportional to the sine of the initial angle, *i.e.*, the angle from which that beat started.

The force, when in the act of starting from its initial angle, is

is kinetic. At all intermediate moments the energy is partly potential and partly kinetic, the sum of kinetic and potential energy being the constant measure present alike at initial and vertex and final moments. Thus, for example, in Fig. 1 the initial potential E = the vertex kinetic K; and, at every interval between E and K, we see $e + k = E = K$.

As the force is exhibited by the sine, and the energy by the versine; so the time and speed of unresisted pendulum are shown by the arc of amplitude; and the same interchanges or reciprocations of potential initial and final, and of kinetic vertex phases characterise the time and speed and the arc of amplitude as in the cases of the force and energy. Thus in Fig. 1, s being the kinetic and v the potential speed, $s + v = V$.

And so, whether we speak of force, energy, time, or speed, if we let P stand for the potential, and K for the kinetic, and C for the combined or total value of motion, we can express, by the common formula $P + K = C$, the constant value of force, energy, time, or velocity, present at every moment of the unresisted beat.

It may seem absurd to talk of a constant value of velocity as pervading a beat whose actual velocities are known to be continually varying. But, when the essentially reciprocal nature of all motion is clearly understood, it becomes evident that the absurdity lies in regarding the various intermediate kinetic values of speed between the ends and middle of pulse as proper values of finished, or fully developed, speeds, which indeed they are not; for they really are, as we have now seen, merely the kinetic phases or portions of that constant value of speed which finds purely kinetic expression at vertex only.

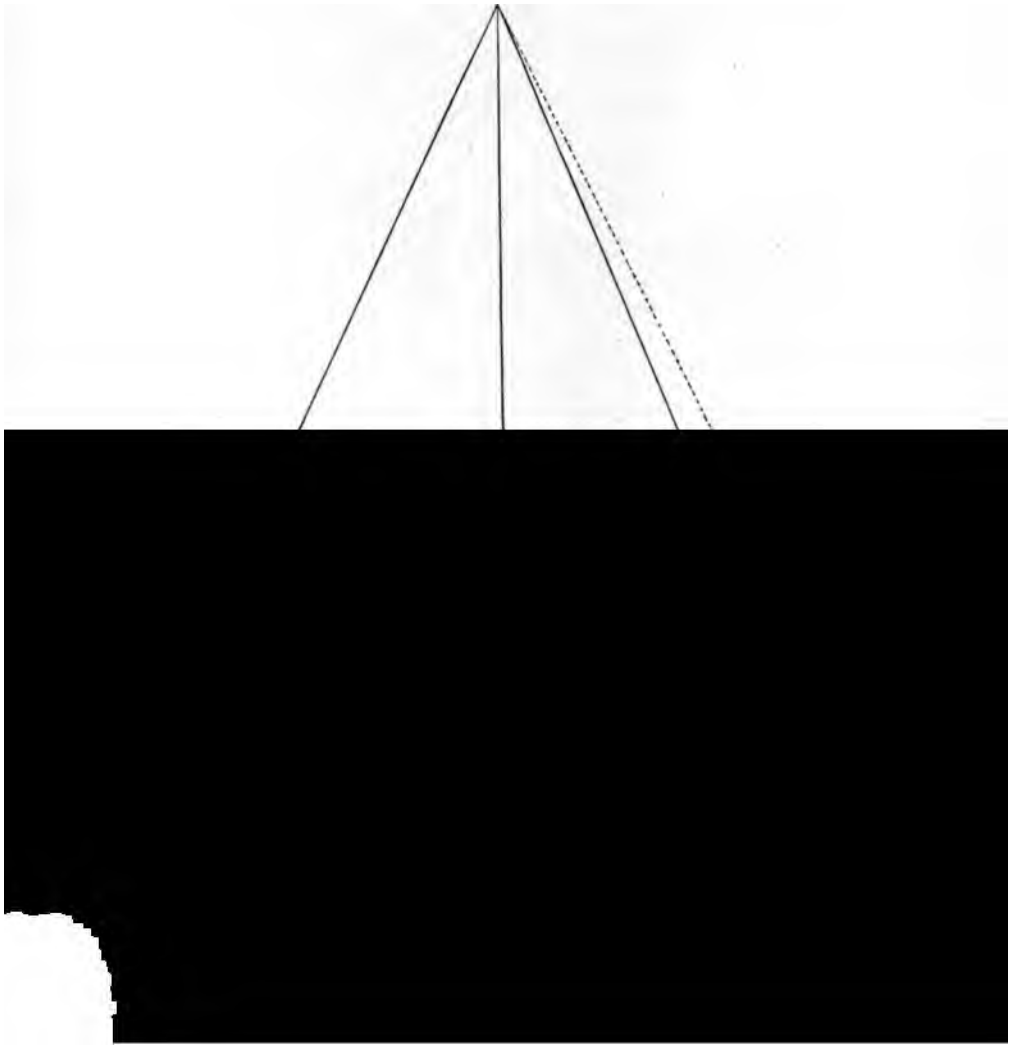
We are accustomed to speak of quarter moons, half moons, three-quarter moons, and full moons; but in using this language we never forget that the reality is the full moon all the time. So, in phases of a pulse of speed, while we may and must distinguish the progressive visible kinetic phases as incidental to their various points or angles of the arc of motion, we should never lose sight of the fact that the pulse is possessed of the full speed value all through.

To regard the varying intermediate kinetic velocities as the only speed values of the beat, thus ignoring the complementary potential values of these same kinetic velocities, is to confuse and confound the process of motion, and render the interpretation of pendulum behaviour utterly misleading.

Both sides of the beat (*i.e.*, the initial and final sides) of unresisted pendulum are alike; as shown by the symmetrical diagram, Fig. 1. The whole energy, E, potential at the initial angle of the unresisted

pendulum, having, throughout the first half of the beat, converted the inertia of the bob's mass into momentum, is, throughout the final half of the beat, engaged in reconverting the bob's momentum into inertia. No energy escapes in these transitions; and so the final angle, Z, is equal to the initial angle, A.

The symmetry of the performance of the ideal unresisted pendulum distinguishes it from the real resisted pendulum, whose performance is always more or less unsymmetrical, according to the amount of resistance involved. In place of the symmetrical (Fig. 1) we obtain, by experimenting with the real pendulum, the unsymmetrical (Fig. 2), which we may now examine more particularly. Here, in Fig. 2, we have not only the lobsidedness to characterise it, but also some new features not present at all in Fig. 1.



The following specification of symbols will now be necessary in examining the details of the resisted pulse of speed and power :—

E_0	= initial	versine	= initial energy of resisted beat.		
E_1	= final	,,	= final	,,	,,
e	= decrement	,,	= escaped	,,	,,
F_0	= initial	sine	= initial force		,,
F_1	= final	,,	= final	,,	,,
f	= decrement	,,	= escaped	,,	,,
V_0	= initial	arc	= initial speed		,,
V_1	= final	,,	= final	,,	,,
v	= decrement	,,	= escaped	,,	,,

Reference to Fig. 2 will show that $E_0 - e = E_1$; and $F_0 - f = F_1$; and $V_0 - v = V_1$. Thus the pendulum teaches us that e is the price of the beat in terms of energy; and that f is its price in terms of force; and that v is its price in terms of speed. If we would keep our stock of energy or force from running low, we must replenish it at each beat to the measure of e and f, and only by so doing can we maintain the speed.

We must, so to speak, "keep up our position" by earning a fresh penny for every penny we spend. The pendulum itself has no earning capacity, it is a spender merely; and is constantly needing new impulse to keep it going at any uniform swing of speed. We have seen that e is the amount of energy to be paid per pulse of resisted speed to maintain the speed. The question now arises, what is the speed of the resisted pulse for which this price is paid?

The answer is, that e is the payment in full for the resisted speed in full.

In the case of the unresisted pendulum, we have seen that the complete value of the speed (or speed in full) is expressed at the initial and final moments of beat in purely potential, and at the vertex moment in purely kinetic, phase; and that the real value of the motion is uniform throughout all the phases of phenomena, and all their translations and transitions, as the mass of the moon is uniform throughout its monthly transformations. This would also be true in the case of a resisted pendulum, if propelling force were continually supplied, compensating at every moment the loss by escapement.

Where such compensating force is applied to the resisted pendulum (as, for example, in the clockmaker's most perfect "escapement beats") the pendulum reaches at the end of each beat as high an angle as it started from, and the oscillation resembles that of an unresisted pendulum. But in the case of the resisted pendulum whose escapement is uncompensated, the speed value is not constant throughout the beat, but dwindles, more or less, according to the amount of resistance.

Every function of the arc of motion, as the pendulum plainly shows, suffers its share of the mutation inflicted by resistance. Thus, for example (see Fig. 2), E_0 is reduced to E_1, F_0 is reduced to F_1, V_0 is reduced to V_1, and the original arc, A O Z, is reduced to A O Y; for thus energy dwindles with versine, force dwindles with sine, and speed dwindles with arc. In a word, the speed value of a resisted uncompensated beat varies during the beat by dwindling; and the *e* is the energy paid in full, not for the speed in full at its best, nor at its worst, but at its mean value.

The best value is present, potentially, at the initial moment of the pulse; and is represented by the E_0, energy; F_0, force; and V_0, speed. The worst value is present, potentially, at the final moment of the pulse; and is represented by the E_1, energy; F_1, force; and V_1 speed.

We may likewise take A O Z as representing the best value of speed, present at the initial moment, potentially; and then, by the same rule or measure, the mean value of speed, present, kinetically, at the vertex moment of the pulse, is represented by A O Y. Thus, as it were, graphically and automatically, the pendulum performs its own integrations.

Let us say we are dealing with a cycloidal pendulum; or with any harmonic vibration, *i.e.*, with any reciprocating motion whose period of pulse is constant for all amplitudes. We know that in unresisted harmonic vibrations A O Z is in its changing of amplitude always proportional to $\sqrt{\text{energy or versine}}$. It therefore follows that the mean energy of the resisted harmonic pulse is $= E = E_0 \times \frac{(A\,O\,Y)^2}{(A\,O\,Z)^2}$.

This A O Z measure of speed is the measure also of the travel of the unresisted pendulum; and A O Y measures likewise the actual travel of the resisted pendulum. This arc measure, A O Z for unresisted, and

mean speed of A O Y per beat (*i.e.*, per half revolution) will roll that pendulum bob, wheel, or cylinder along a level floor, free of ties, at the continual vertex speed = 2 × A O Y per half revolution; because in the latter case there is no fixed centre to absorb by reaction half the energy, $= \frac{E}{2}$; and so the whole energy, = E, is devoted to the momentum of the rolling mass.

But when the rolling mass is not solid, but fluid, although it has no attachment to any station, and is quite free to roll, this roller or wave of fluid mass realizes only the mean speed = A O Y per beat; because the mass in motion, which, in the case of the solid roller, is absolutely constant, in the case of the fluid roller, is absolutely inconstant; and this inconstancy of fluid roller mass has the same effect on the speed of fluid roller as the attachment to stationary centre has on the speed of the solid roller, reducing its vertex velocity from a continuing to a momentary phase, and so reducing the speed from 2 × A O Y per beat to a mean speed = A O Y per beat.

Now, in the case of an ideal, unresisted pendulum, we are dealing with a solid mass only; a solid mass revolving, or vibrating, about a stationary centre at a mean speed = A O Z per beat.

But, in the case of any real, resisted, pendulum, we are dealing not only with the solid mass of the pendulum, but also with the fluid mass which is permanently disturbed by its motion—*i.e.*, the mass (not of the wave of replacement, whose useful reaction compensates its inertial resistance, but) of the wave of escapement.

The solid bob is tied to a stationary centre, and therefore revolves at the mean speed = A O Y per beat. The wave of permanently disturbed fluid, though untied to any stationary centre, and so quite free to roll away from its starting point, is handicapped, so to speak, by the absolute inconstancy of its mass, and, therefore, reaches only the same mean speed as the pendulum bob, viz., A O Y per beat.

Thus it comes about that, the effect of fluid wave mass inconstancy being equivalent to the effect of attaching solid mass to stationary centre of revolution, the bob and its wave of fluent mass always move at the same mean speed per beat.

We have seen that *e* (Fig. 2) is the measure of energy expended per beat in propelling the resisting mass of permanently disturbed fluid.

A much larger mass of fluid (viz., the wave of replacement) is temporarily disturbed; but the reaction of the temporary disturbance compensates the energy; so that no loss of energy arises from resistance of fluid to temporary displacement.

It is the relatively small mass of permanently disturbed fluid whose waves, refusing to give back to the solid wave-creating mass of the pendulum the energy expended in their evolution, continually escape from the sphere of the pendulum's motion, carrying their energy off with them. These are the waves to which the resistance of a pendulum, or of any other body, moving through fluid, is due.

Out of a mean measure, or stock, of energy, = E, these escapement waves steal away with a measure, = e, at every beat. So we see that E − e = measure of energy engaged in momentum of solid mass of bob, while e = measure of energy engaged in momentum of fluid mass of escapement waves, when the bob and the escapement waves have, as indeed they cannot help having, the same mean speed = A O Y per beat, and the same vertex speed = 2 × A O Y per beat.

Throughout the pendulum beat the fluid mass of the escapement wave experiences, simultaneously with the solid mass of the bob, the same potential and kinetic variations of phase. And so, with the wave as with the bob, the vertex speed is twice the mean speed; that is to say, the crest of the wave moves at twice the speed of its mass. Hence, when waves are left free to proceed by themselves, their crests present an appearing and disappearing intermittency of phenomena, alternately seeming to outrun their own mass and to vanish; reappearing, to repeat the outrunning or overleaping phase.

Seeing that with a given measure of energy, = E, we can have the option of propelling the given solid, free from any attachment, at a continuous speed = 2 × A O Y per beat; or, attached to a stationary centre of revolution, at a mean speed = A O Y per beat, the converse option holds equally good.

To make this measurement from the method of a continuing straight forward speed involves a tank of great length. But by the alternative method the same true results can be obtained within a tank of small length.

Time will not now permit of a description of this short tank method in any detailed degree. But the manner in which the invaluable option above specified is usefully applied to the requirements of the modern shipbuilder and naval architect may be briefly summarised, or sketched, as follows :—

A small scale ship model supplied by the shipbuilders, and preferably dug out of one block of wood, is ballasted in the tank to its proper load-line, and so attached to the pendulum bob suspended above the tank that the ship floating in the water, without having her displacement changed by the force of the pendulum, may share the speed of the to and fro motion with the pendulum.

Throughout this paper the decrements of amplitude have been referred to as merely due to the resistance offered by the air to the motion of the bob.

Now, in point of fact, the resistance thus occasioned is, in practice, extremely small ; and is generally so infinitesimal as to be negligible : for the great length of pendulum admits of operations being conducted within moderate amplitudes, wherein the air resistance, to solid lead bob supported by very sensitively fixed and accurately adjusted fine wires, is barely appreciable.

Hence the decrements of amplitude obtained by experiment are due almost wholly to the resistance offered by the water to the motion of the ship model ; and this resistance of the model at any given speed to which the pendulum force raises her is of course what the shipbuilder and naval architect need to know.

The measurements of decrements are made with great accuracy by means of the graduated reading bar and needles hanging from sliding adjustable verniers, as described in the earlier part of this paper.

Everything already stated herein as true of the measures of energy, force, and speed thus obtained by pendulum experiment, applies in every particular to the experimental results when these are due to the resistance of the ship model and not to the resistance of the bob.

Thus the e (decrement of versine) yielded by one beat of pendulum with ship in tow is the true measure of energy expended in that beat on the escapement waves of water created by the ship's motion. And so, multiplying this decrement of versine by the weight of the pendulum,

and dividing by the time of the beat, we get, as product, the power required to keep that ship model beating about a stationary centre at the mean speed represented by her actual travel divided by the actual time per beat.

Then, on the principle of the option above demonstrated, we know that the power which can do this is the same measure of power as will drive that ship model unattached to any stationary centre right ahead at a uniform speed exactly equal to her vertex speed actually attained ; *i.e.*, double the mean speed actually attained.

Now, as regards the time of beat, we have throughout this paper in each case, viz. :—(1) That of the unresisted pendulum, (2) that of the resisted pendulum, and (3) that of the ship model attached to pendulum, accepted each particular case's period of beat (whatever its duration) as our unit measure of time in that case only. So that in regard to time of beat each tub, so to speak, has been left to stand on its own base.

So far as the writer's experience goes, he has not been able to find, experimentally, even in cases where the resistance was abnormally great, any very appreciable change of pendulum period due to mere resistance. Thus cases (1) and (2) above-named, will always, in ordinary experimental practice, be found to have no difference of period.

But in case (3) the change of time of beat will be anything, within certain limits, that the experimenter chooses to make it, according to the proportion, as determined by himself, which the ship model's displacement weight bears to the weight of pendulum bob. For the weight of bob is the measure of motive force, and when, in addition to its own mass inertia, it has to overcome the inertia of the ship model's displace-

Thus when, for example, pendulum bob weight = ship's displacement weight = 1: if the pendulum be unattached to ship model we have $\frac{\text{bob}}{\text{bob}} = \frac{\text{towing weight}}{\text{weight towed}} = \frac{1}{1} = 1$ = accelerative force; and $\sqrt{1} = 1$ = time of beat = speed of beat. But, when pendulum is attached to ship model, we have $\frac{\text{bob}}{\text{bob + ship model}} = \frac{\text{towing weight}}{\text{weight towed}} = \frac{1}{1+1} = \frac{1}{2}$ = accelerative force

$$\left.\begin{array}{l} \text{and } \sqrt{\frac{1}{2}} = \cdot 707 = \text{speed of beat} \\ \text{and } \sqrt{\frac{2}{1}} = 1\cdot 414 = \text{time of beat} \end{array}\right\} \text{as above stated.}$$

In these expressions the effect of resistance on period of beat is ignored, because, even if ever appreciable, it is so insignificant. For though, as already explained, resistance considerably shortens the travel, as, for example, from A O Z to A O Y (Fig. 2), and in that way lowers the speed, it does not affect the speed very appreciably by altering the period of beat, except perhaps in the case of resistances so abnormally great as never to occur in ship speeds.

In proof of which: take the case of a ship whose escapement wave mass (*i.e.*, her resisting mass) is $= \frac{\text{her displacement mass}}{\text{say } 200}$, while pendulum bob = displacement mass of model. If we neglect the question of effect of resistance on period of beat, we write, Period $= \sqrt{\frac{2}{1}} = 1\cdot 414$. If we take account of the assumed effect of resistance on period of beat, we write, Period $= \sqrt{\frac{2\cdot 005}{1}} = 1\cdot 416$. So the error due, in this fairly representative ordinary case, to a neglect of the attributed influence of resistance on period of beat is only about $\frac{1}{700}$th time; if indeed the time is influenced in this way at all; and this must depend on whether the fluid medium is viscous or not.

And now, in regard to another small matter, it seems scarcely necessary to point out that no appreciable error is due to the difference of horizontal travel of ship and circular travel of pendulum; for not only is the excess of arc length over sine length extremely insignificant within those moderate angles at which the experiments occur, but also the fact that the pendulum has to tow the ship a less distance than the pendulum's own bob travel is a compensating fact, and leaves no residue of error. This matter is too small to dwell upon. It is only mentioned to show that it has not been overlooked.

Amongst those to whom the line of thought opened up herein is new, the question will naturally arise—How can a vertex speed, gained in one or two seconds be dynamically equivalent to a straightforward speed gained by the same model in an accelerating run of many seconds' duration? The one state is so suddenly and the other so gradually attained that surely the two cannot be strictly equivalent each to the other?

And yet which of us would prefer a photograph of a moving crowd, which was many seconds in being taken, to one which was taken in a fraction of a second? The answer to this question would depend not a little on the preparation of the instantaneous plate; and, similarly, in the case of the pendulum beat, the question of preparation is of the first importance. It is all very well to judge slightingly of an effect because it is obtained in a few moments. But how was that effect made possible?

A cannon which takes a minute to go off is not necessarily more effective than one which goes off in less than a second; the preparation of the potential, in the shape of powder, etc., would be a very material element of efficiency in such case. Let us then enquire, reverting to the pendulum meter, how did this propulsive energy, $= e$, contrive to store the much greater mass of energy, $= E$, which is present kinetically at the vertex moment of this ship model's motion? Clearly that must have been stored before the one beat now in question could begin to expend the same in that beat.

The history of the storing transaction may be recorded thus:—

The bob and ship were hanging or floating motionless at vertex, when the feeble impulse, whose energy was $= e$, was imparted repeatedly to them in a series of beats agreeing in time intervals with the period of the pendulum-ship oscillations.

and the escapement waves grew bigger, they went on appropriating a larger and larger share of the momentum derivable from each e beat; until, finally, on the attainment of the highest angle possible to e, and the full swing of speed according therewith, the escapement wave was big enough at each beat to consume the whole e put in at each beat; thus leaving the bob and ship model to continue their motion in virtue only of the store of momentum which they, by this tedious process of getting up speed, had gradually accumulated.

Of course the smaller the e in ratio to E (and, by the same rule, the smaller the resisting mass of the full speed escapement wave in ratio to the mass of a ship's displacement) the longer will be the period of acceleration, and the greater the number of e impulses to administer. Now all this preparatory process, or something dynamically equivalent thereto, must be gone through before the ship model can shoot away in the tank from her initial angle, and gain her vertex speed in a second or two. The leashing up of the pendulum and ship to the initial angle ready for starting is equivalent to storing energy by the beating up process.

In fact the ship has had to be got up to her speed before she starts at the burning of the leash; and the mere act of starting from the initial angle of the pendulum speed is, when clearly understood, perceived to be in itself a proof that the model starts therefrom, not with speed to get up, but with speed already up.

Seeing that the initial energy, $= E_o$, is stored as above described, by a long process of beating up, or accumulating, just as the enormous energy of a real ship's full speed momentum is gathered slowly from the comparatively feeble impulses of the propeller, we must not, in oblivion of these facts of preparation, regard, short-sightedly, the initial state of the ship model in the pendulum meter, at the moment when the leash is just burnt, and when the bob is really possessed of the E_o measure of energy, as a state of zero energy and zero speed; and we must not be so far led away by superficial appearances as to think the ship model gains her speed suddenly in that one-half beat from initial angle to vertex; for indeed she was literally under full weigh at the moment of her starting from the initial angle.

It will probably occur to someone to object that if the ship model were in the kinetic sense underweigh at a realised speed engaging the energy E_o, she would be enclosed by a wall of escapement waves; but that the ship in the pendulum meter on the point of starting from the initial angle, though undoubtedly endowed with E_o, is enclosed by still water.

But as the moon renders herself visible and invisible by turns, so does

the wave. In the case of the ship model starting from the initial angle, the wave, though invisible, is there; as truly as the moon is in the sky on a pitch-dark night. We cannot have the E_o potential at the initial moment of motion, without having the potential wave attending it. We might as well expect to find pressure without force, as to find E_o without its suppressed, potential and invisible, but none the less really present, wave.

We may say of a block of marble, the statue is there, before the sculptor has begun to work even in thought upon it.

It is not, however, in any such remote ideal sense that we must regard the speed wave as being invisibly present at the initial moment of the ship model's motion: for in this case the preparatory work essential to the creation of that wave has been done; and it is because the work as well as the water is present at that starting angle that the wave is there, in a much more real sense than the statue is present in the unwrought marble.

If the ship model were going at full speed in the ordinary straightforward way with total energy of motion $= E_o$, and the propelling power were suddenly withdrawn (that is to say the propelling e impulses were discontinued), and if she were allowed to shoot onwards by her acquired momentum for a space of time equal to the period of the beat of same ship model in pendulum meter, the initial kinetic energy, $= E_o$, would dwindle to a final kinetic energy $= E_1$, and the mean value of energy kinetically present during the interval would be $= E$: the amount of energy lost during the interval on the escaping waves being $= e$.

The only difference between the conditions as thus experienced and the conditions experienced with the same E_o initial and E mean, and E_1

swing, the exact measure of power and speed the ship model expends and enjoys in that one beat; and this is the power and speed due to that ship in continuance of that same beat at uniform periods; such continuance being the true condition of what is commouly called "uniform speed."

The common conception of uniform speed has been hitherto that of velocity continuously kinetically equal or constant. But the pendulum plainly teaches that at no two adjacent moments are the energy or velocity of uniform speed constant, and that throughout the universe we should seek in vain for one linear foot or even inch of motion truly answering to the common conception of uniform speed. The true uniformity of speed consists in the constancy of its pulse periods, and in the exact similitude of all the pulses in all their coincident or corresponding features and phases.

When a ship is so attached to a pendulum as to share its motion without having her displacement mass increased, decreased, or otherwise changed by the attachment, the experimentally obtained diagram of one beat is a diagram of all the beats of that rate of speed with that ship model, for all are alike. So the pendulum meter, in one beat of motion, obtains, as it were, an instantaneous likeness of the ship's hydrodynamic features, by which her speed for any power, or power for any speed, is clearly portrayed. And if we could, when the ship is going at uniform speed, get a thousand such pulse likenesses taken in succession we should be no wiser, for they are all alike.

A ship when getting up speed under a constant power has a mean speed = half her full speed; so that, if the power be constant, the ship travels, in getting up her speed, half the distance she would travel in the same time at her full speed.

That which is thus true of the whole series of waves, in their effect upon the ship, and in her effect upon them, is true likewise of every individual wave; for if it were not true of the part it could not be true of the whole. For the same reason the ship's mean speed in the meter is, as before shown, half her full speed.

The most convenient form of expression of the experimental results obtained from the pendulum resistance meter is as follows :—

Let W lbs. = motive weight = bob weight.
h ft. = loss of potential head = decrement, of versine.
t secs. = actual time of beat.
V knots = actual vertex speed.

Then hW ft.-lbs. = work done per beat to gain, or maintain, V.

and $\frac{hW}{550t}$ = E.H.P. doing the work of V.

There have now been a large number of models tested in the meter: chiefly ocean-going cargo boats. In order that all may judge of the work of the meter for themselves, a few E.H.P. curves taken by the meter, and the corresponding I.H.P. curves obtained from the ships on the measured mile, progressive speed trials, are given by kind consent of Mr. James Laing, Messrs. C. S. Swan & Hunter, Messrs. W. Doxford & Sons, and Mr. Macoll for Messrs. S. P. Austin & Son.

The corresponding E.H.P. and I.H.P. curves on this diagram (Plate XIV.) are distinguished by the initial letters A, B, C, D, as also are the corresponding curves of $\frac{\text{E.H.P.}}{\text{I.H.P.}}$, or efficiency curves.

In accordance with the principles of interpretation herein set forth, and in consonance with Reech's law of corresponding speeds, a great deal of the calculation needed to reduce the decrements of pendulum amplitude experimentally observed to useful terms of knots and E.H.P. of the full-sized ship, has been done by anticipation, and the results engraved in coefficients of speed and power on the reading bar at the various angles. By means of these coefficients the labour of calculation is so greatly lessened that the instrument is, to a large extent, a ready reckoner; and the operator is therefore able to gather the needful information with greater expedition as well as with less liability to clerical inaccuracy.

In the permanent calculations from which the engraved coefficients have resulted, the cycloidal correction (though very slight within the angles concerned) has been duly made.

Nearly two years have now elapsed since the bar was engraved; and, though he has had much cross-questioning to answer, the writer has not yet found occasion to regret one coefficient figure, or to wish one altered

and unmistakable language as the subject necessitates, those fundamental and universal principles, hitherto commonly disregarded, upon which the pendulum meter's utility depends.

A visit to the tank would serve to render plainer some of the above statements; and it would afford the writer much pleasure to explain at the tank any practical details which have not been dealt with in this paper.

The discussion on Mr. Caws' paper was adjourned, and the meeting terminated.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893-94.

PROCEEDINGS.

FOURTH GENERAL MEETING OF THE SESSION, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, BARRAS BRIDGE, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, JANUARY 16TH, 1894.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on December 20th, 1893, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. W. Kilvington and J. C. Stirzaker to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Ayre, James Reay, Ship Draughtsman, 16, Neptune Road, Wallsend-on-Tyne.
Bosi, Guiseppe, Engineer and Naval Architect, 157, Roker Avenue, Sunderland.
Fraser, Thos. S., Electrical Engineer, Messrs. E. Scott, Mountain, & Co., The Close, Newcastle-on-Tyne.

MEMBERS (LATE GRADUATES).

Bell, Geo. Arthur, Marine Engineer, 29, Hawthorn Street, Newcastle-on-Tyne.
Coleby, James W., Engineering Draughtsman, Boundary Street, Willington Quay-on-Tyne.
Cooper, W., Jun., Engineer, 11, Ridley Place, Newcastle-on-Tyne.
Ewen, Alex., Mechanical Engineer, St. Mary's Island, Whitley-by-the-Sea.

Henshall, Samuel, Ship Draughtsman, 6, Hume Street, Millfield, Sunderland.
Pringle, Alfred, Ship Draughtsman, 10, Somerset Terrace, Walker-on-Tyne.
White, Ernest T., Engineering Draughtsman, 16, Abbey Terrace, Gateshead-on-Tyne.

GRADUATES.

Bowden, John, Apprentice Engineer, Sheriff Mount, Gateshead-on-Tyne.
Carr, Ralph, Jun., Apprentice Engineer, Thornleigh, Clayton Road, Newcastle-on-Tyne.
Forster, Edgar S., Apprentice Engineer, 2, Shaftesbury Terrace, Gateshead-on-Tyne.

GRADUATE AWARDS.

The Graduate awards for the last session were delivered by the President to the following members:—

1. Mr. John King, for his paper on "Floating Caissons."
2. { Mr. A. Young, for his paper on "A Modern Theory of the Rolling of Ships."
   { Mr. J. Brentnall Duckitt, for his paper on "Continuous Current Dynamos."

Mr. W. Hök's reply to the discussion on his paper "On a Method of Comparing Steamship Performances and of Estimating Powers and Speeds of Ships" was taken as read.

By request of the Council and in response to a communication received from the Marine Department of the Board of Trade, Mr. J. R. Fothergill read a paper on "Mercantile Marine Engineers."

MR. W. HÖK'S PAPER "ON A METHOD OF COMPARING STEAMSHIP PERFORMANCES AND OF ESTIMATING POWERS AND SPEEDS OF SHIPS."

Before replying to the discussion Mr. Hök made the following additions to his paper:—

THE METHOD SIMPLIFIED (see page 22).

Mr. Froude pointed out in his communication that by introducing the expression for

$$p_s = \frac{I}{U} - q \quad . \quad . \quad . \quad . \quad . \quad . \quad (6) \text{ page } 24$$

into the expression for

$$p_D = p_s \times \tau \quad . \quad . \quad . \quad . \quad . \quad . \quad (6\tfrac{1}{2}) \text{ page } 24$$

we obtain the following expression for

$$p_D = \frac{I}{D\sqrt{l}} - q\tau \quad . \quad . \quad . \quad . \quad . \quad . \quad (9).$$

where p_D = indicated horse-power per ton of displacement of 100 feet model at speed V_m,

I = indicated horse-power of ship at speed V,

D = displacement of ship,

l = ratio of linear dimensions of ship and model $= \frac{L}{100}$,

q = skin friction correction (Diagram 1, Plate I.),

and $\tau = \frac{l}{D} \times \frac{S}{100} = \frac{1}{100} \times$ skin-fulness of displacement.

This expression had been previously deduced by the writer, but he had discarded it because he had overlooked the fact that equation (9) led to the abolition of U, page 23. This being now pointed out by Mr. Froude, he acknowledges at once that expression (9) is far preferable to use to the steps proposed in the paper. Besides it has other advantages than the mere abolition of U. It seems to make the method altogether more comprehensible and simple, and to put the whole matter in a much clearer light.

The further simplification of the method, which the writer gave notice of at the Hartlepool meeting, consists in giving such a form to the expression for τ as to do entirely away with the wet surface S, and to enable one to take τ from a diagram (Diagram 13, Plate XV.), consisting of a single curve, without any calculation whatever. Or it can also be calculated from the following formula:—

$$\tau = \frac{1{\cdot}6}{\sqrt{D_m}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10).$$

$$= \frac{1{\cdot}6\, l\sqrt{l}}{\sqrt{D}} \quad . \quad . \quad . \quad . \quad . \quad (11).$$

(For the mathematical deduction of τ as expressed by (10) or (11) and another simple expression for the wet surface see Appendix E, page 128.)

Thus the whole process of converting ships into 100 feet models is as follows:—Given length, displacement, speed and power,

Find $l = \frac{L}{100}$.

" $\sqrt{l}$.

" $V_m = \frac{V}{\sqrt{l}}$.

" q for length L and speed V_m from Diagram 1.

" τ by formula (10) or (11), or Diagram 13.

" $q\tau$.

" $\frac{I}{D\sqrt{l}}$.

Deduct $q\tau$ from $\frac{I}{D\sqrt{l}}$ if $L < 100$ feet.

Add $q\tau$ to $\frac{I}{D\sqrt{l}}$ if $L > 100$ feet.

And we have p_D = I.H.P. per ton of displacement for 100 feet model at speed V_m.

Estimating Powers and Speeds.

The corrected curves on Diagrams 9, 10, and 11 (Plates IX., X., and XI.) are used in estimating the powers and speeds of ships. Let L, B, d, D, and V be the length, breadth, draught, displacement, and speed of ship (strictly speaking, only L, D, and V are needed). What power (I) is now required?

Make ship into a 100 feet model

Now select among the 100 feet models (Appendix C, page 39) the one most similar, especially in regard to block coefficient of fineness (ω).

Take from Diagrams 9, 10, or 11 the power per ton of displacement for the 100 feet model at speed V_m ($= p_D$).

Take q from Diagram 1 for given L and V_m,

" τ " " 13 " D_m,

and I.H.P. for the actual ship L feet long

$$= (p_D + q\tau)\, D \sqrt{l}$$

at speed V.

Add $q\tau$ to p_D when $L < 100$ feet.

Deduct $q\tau$ from p_D when $L > 100$ feet.

If, on the other hand, the power is known and the speed required, the procedure is very similar. However, we have here a slight difficulty to contend with, being the evaluation of the skin friction correction q, owing to the nature of Diagram 1, Plate I. We have first to guess V_m, which is indeed the quantity we want to determine, but this is easily done in the simplified method by first finding $\frac{\text{I.H.P.}}{D\sqrt{l}}$; then find the speed corresponding to this value from the speed diagrams, and take that speed or something slightly more if $L > 100$, or less if $L < 100$, for the evaluation of q.

On the supposition that the skin friction correction is omitted the I.H.P. per ton of displacement of the 100 feet model is—

$$p_D = \frac{I}{D\sqrt{l}} \text{ at speed } V_m = \frac{V}{\sqrt{l}}.$$

Hence it follows that in order to find the powers per ton of displacement and speeds of any other similar ship of length L, we need only multiply

p_D by $\sqrt{l}$,

and V_m " $\sqrt{l}$,

which is certainly as interesting and useful to know as it is simple.

The power is then easily obtained by multiplying by D, which power exceeds the actual power in ships of 100 feet in length, and is less than the actual power in ships under 100 feet in length by the amount due to the skin friction correction.

Examples of Powers and Speeds calculated by the Simplified Method.

In order to show the application of this method and its extreme simplicity, let us estimate the power and speed of the following ship:—Length, 245 feet; breadth, 32 feet; draught, 13·33 feet; displacement,

1,550 tons; block coefficient, ·520; speed, 15 knots; indicated horse-power?

Here $l = 2{\cdot}45$;	$\sqrt{l} = 1{\cdot}565$;	$l^3 = 14{\cdot}71$
$V_m = 9{\cdot}58$;	$q = {\cdot}33$;	$p_D = {\cdot}837$
$D_m = 105{\cdot}4$;	$\tau = {\cdot}156$;	$q\tau = {\cdot}051$
$\omega = {\cdot}520$;		
$B_m = 13{\cdot}06$;		$p_D - q\tau = {\cdot}786$
$d_m = 5{\cdot}44$;		

$$\frac{I}{D} = {\cdot}786 \times 1{\cdot}565 = 1{\cdot}230;$$

$$\text{and } I = 1{\cdot}230 \times 1550 = 1906 = \backsim 1900 \text{ I.H.P.}$$

If the skin friction correction is neglected :—

$$\frac{I}{D} = {\cdot}837 \times 1{\cdot}565 = 1{\cdot}310,$$

$$\text{and } I = 1{\cdot}310 \times 1550 = 2030 \text{ I.H.P.}$$

Should, on the other hand, the power be given and the speed required, the procedure is as follows :—

Find the value of $\dfrac{I}{D\sqrt{l}} = {\cdot}786.$

Ascertain from the diagrams what speed this value of p_D gives. Add a slight amount to the found speed, and we can with sufficient accuracy put :—

$V_m = 9{\cdot}58$ knots;	q is then $= {\cdot}33$;	$\dfrac{I}{D\sqrt{l}} = {\cdot}786$
$D_m = 105{\cdot}4$ tons;	$\tau = {\cdot}156$;	$q\tau = {\cdot}051$
		$p_D = {\cdot}837$

Corresponding $V_m = 9{\cdot}58$ knots,

[redacted]

Using the present notations it takes the form of

$$\frac{S_m}{D_m} = \frac{lS}{D}$$

for the 100 feet model.

As the value of τ is $\frac{l}{D} \times \frac{S}{100}$, it follows that

$$\tau = \frac{1}{100} \times \text{skin-fulness of displacement of 100 feet model,}$$

$$= \text{actual skin-fulness of displacement of a 10,000 feet long ship.}$$

τ could have been made to express the actual skin-fulness of displacement of the 100 feet model, but the values of q, or the skin friction correction, would then have been so small as to cause confusion.

As to the simplification of the expression for $\tau = \frac{l}{D} \times \frac{S}{100}$.

The expression for τ contains the wet surface, which is not generally known without a separate computation. But let us introduce into τ the expression for S found on page 25 in the paper.

Then
$$\tau = \frac{l}{100D}\left[\frac{35D}{d} + 2dL\right]$$

$$= \cdot 35\left[\frac{1}{d_m} + 5\cdot 714\,\frac{d_m}{D_m}\right] \quad . \quad . \quad . \quad . \quad . \quad (12)$$

when d_m = draught of 100 feet model, and

D_m = displacement of 100 feet model.

Supposing now that for a series of values of D_m we calculate τ for varying d_m, we obtain a series of curves of $f\,(d_m, \tau)$, one for each value of assumed D_m. One of the properties of this series of curves is that each curve has a minimum point at some value of d_m; also the variation of τ in the vicinity of these minimum points is small for a considerable variation of d_m. If, then, it should be fortunately so in practice that the draughts d_m of 100 feet models for given displacements D_m, are actually of such values as to correspond to those at or about the minimum points of curves $f\,(d_m, \tau)$, we can with sufficient accuracy express τ in terms of D_m alone. Let us see if this is possible.

For this purpose, assume constant D_m and differentiate τ as expressed by (12)

$$\frac{d\tau}{d\,(d_m)} = \cdot 35\left[-\frac{1}{d_m^2} + \frac{5\cdot 714}{D_m}\right].$$

To find the minimum point put $\frac{d\tau}{d\,(d_m)} = 0$, and

$$d_m = \frac{\sqrt{D_m}}{2\cdot 39} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13).$$

If now, as it was said before, d_m in actual practice can be expressed by equation (13), it is possible to express τ in terms of D_m alone.

D_m. (Tons.)	d_m. (Feet.)
20	1·87
30	2·29
50	2·96
70	3·50
100	4·18
150	5·12
200	5·92
300	7·25
400	8·37

The table above is calculated from equation (13), and a comparison with the draughts d_m in the list of ships (Appendix C, page 39) shows that for the whole range of displacement the draughts in the above table closely correspond to the draughts in the list, with the exception perhaps of yachts. It will also be noticed that the draughts d_m from equation (13) are generally somewhat smaller than the actual draughts in Appendix C; but it must be remembered, firstly, that the variation of τ is insignificant in the vicinity of the minimum points, and, secondly, that the tendency of our time is to make ships shallower in proportion to length. With regard to yachts, they are generally short, and the skin friction correction as here applied is very small compared with the actual power. The error in the value of τ for yachts may, in exceptional cases amount to 10 per cent., which means at the outside an error of $\frac{1}{2}$ per cent. of the total I.H.P., which is indeed small enough.

So it appears to be tolerably certain that for the mere sake of effecting the skin friction correction we get abundant accuracy by adopting the expression for τ, involving D_m alone.

Hence the simple expression for τ is—

$$\tau = \frac{1{\cdot}6}{\sqrt{D_m}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14),$$

$$= \frac{1{\cdot}6\, l \sqrt{l}}{\sqrt{D}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15),$$

the latter expression stating τ in terms of the displacement of actual ship and of the ratio of the linear dimensions l, and the former in terms of D_m alone.

As the writer thinks that ships' dimensions ought to be, although not absolutely necessary, reduced to those of 100 feet models for comparison and choice of type ship, he prefers to use the expression—

$$\tau = \frac{1{\cdot}6}{\sqrt{D_m}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14),$$

and has constructed a curve of τ for varying D_m calculated from expression (14), which curve is to be found in Diagram 13, Plate XV., and from which τ can be taken without any actual calculation.

NOTE.—While the writer was working at the simplification of τ, Mr. Froude, unknown to him, showed his deep interest in these matters by working for the same purpose at Haslar. He communicated his results to the writer, and, strange to say, both had arrived at equivalent results in entirely different ways independently of one another.

APPROXIMATE WET SURFACE.

The value of τ being also

$$\tau = \frac{l}{D} \times \frac{S}{100} \quad . \quad . \quad . \quad \text{(page 23)},$$

it follows that

$$\text{Wet surface} = S = \frac{100 \times D}{l} \times \tau$$

$$= 16 \sqrt{L} \sqrt{D} \quad . \quad . \quad . \quad . \quad (16)$$

when L = length of ship,

D = displacement of ship,

which expression for the wet surface is extremely convenient in many instances.

The numerical factor in equation (16) must not be considered absolutely constant. It varies with draught and type of ship to some small extent. It is practically constant over a considerable range of draught in ordinary steamers. At very light draughts, however, the factor increases somewhat, but the user of formula (16) can easily ascertain for himself its variation in ships of the type under consideration.

REPLY TO THE DISCUSSION.

Mr. Hök said the really most important question raised in the debate was which was the more correct principle of comparison, either power per unit of displacement or power per unit of surface (or its approximate equivalent $D^{\frac{2}{3}}$)? Theory considered surface, and so did Mr. Young, Mr. Weir, and Mr. Patterson. On his side he had Prof. Weighton, Mr. McGlashan, and Mr. Sivewright. Mr. Froude was neutral.

He had used power per unit of surface for years, but it failed to satisfy him. At low speeds he admitted in the paper that the rate of expenditure of power per unit of surface was more constant (but not much more) for different forms than power per unit of displacement. But at high speeds curves based on the former principle spread out in all directions, and could not be used with confidence except for very similar ships.

On the other hand, curves based on the displacement spread out a little more than curves based on the surface (but very little) at low speeds, but closed together at high speeds, where it was far more important to have constancy of rate.

It might interest the members to know that he had not only used $\frac{I}{S}$ and $\frac{I}{D}$, but also tried $\frac{I}{D^{\frac{2}{3}}}$ and $\frac{I}{D^{\frac{4}{3}}}$. Of these $\frac{I}{S}$ approached constancy at lowest speeds, $D^{\frac{2}{3}}$ at slightly higher speeds, $D^{\frac{4}{3}}$ at higher speeds than $D^{\frac{2}{3}}$, and D at higher speeds still. So in this respect it really did not matter much what comparison was used. Any comparison would be advantageous at some speeds and disadvantageous at others. It was impossible to get (at least at present) a comparison which would be *the* best at all speeds. And then as a matter of common sense, was it

corrective term by which p_D should be multiplied was $\sqrt[3]{\frac{D_m}{D_s}}$. Then use the corrected p_D instead of the p_D from the diagrams. Apart from this he felt convinced, although it could not be proved without exhaustive experiments, that when it came to the question of sea speeds, to the progress of ships among waves, or say on a swell, that is when the speed of the ship was not uniform, but always accelerated and retarded, due to the pitching motion, the mass, or say, the weight or displacement (for ships of equal lengths), constituted by far the most important factor in the resistance at all speeds. And if he also added that no practical comparison and analysis of performances of ships of various types and forms could ever be made unless the principle of I.H.P. per ton of displacement was adopted, he had said enough in defence of his position.

It might also be useful to point out that although the powers did not vary at low speeds as the displacement, it did not absolutely follow that they varied as $D^{\frac{2}{3}}$. They might vary as $D^{\frac{1}{2}}$ or $D^{\frac{5}{3}}$, or something else.

Then they had to consider the introduction of V^3 in the divisor, as suggested by Mr. Froude. This device had the advantage of making the power per unit of displacement fairly constant at lower speeds, so that it could be retained in one's memory. At speeds where the wake-making element was great, the variation of power-value must, however, be so considerable that he doubted very much that the memory could retain it. There was a special inducement to Mr. Froude to introduce V^3, because it magnified the interesting features of the accurately measured resistance curves, *i.e.*, humps and hollows, at the Admiralty experiment works. However, V^3 in the denominator destroyed the most important feature in the speed curve, viz., the rapid growth of power with increase of speed. This raised the question: Should this important feature be sacrificed for the interesting, but, in practical comparison, less important feature of irregularities on the curves? At Mr. Froude's works he should say, yes; in actual practice, *i.e.*, in shipyards, where their only data consisted of trials obtained under varying conditions of wind, tide, and sea, he should unhesitatingly say, no. Besides, notwithstanding the convenience of greater constancy, this device gave hardly such accurate results, for any small variation in the value of the "constant," which might look innocent enough, made a considerable difference in the power when afterwards multiplied by V^3. The only thing of which he in his method had robbed ships was absolute size; but this was indispensable, unless one had an unlimited amount of data at one's disposal.

He now came to the question of the necessity for the skin friction

and engine friction corrections. This matter was perhaps best settled by giving two examples. Assume a model speed curve, the maximum speed of which (V_m) was 12 knots. Let this curve be used for estimating the power required to propel a 400 feet ship 12 knots.

Here V_m is 6 knots,
and p_D is ·15 say,
μ is ·75 (Diagram 8),
q is ·14,
τ is ·16.

Then p_D not corrected for engine friction $= \frac{\cdot 15}{\cdot 75} = \cdot 200$,

and p_D corrected for skin friction $= \cdot 15 - (\cdot 14 \times \cdot 16) = \cdot 128$.

Assuming the displacement of the 400 feet ship = 6,400 tons, the I.H.P. when no corrections were made was $\cdot 200 \times 2 \times 6{,}400 = 2{,}560$, and in the case where corrections were made for engine friction and skin friction $= \cdot 128 \times 2 \times 6{,}400 = 1{,}638$, showing, in the former case, an excess of 922 I.H.P. or 56 per cent., being 17 per cent. for the skin friction and 39 per cent. for the engine friction. Although in most cases the excess, by ignoring these corrections, was not so large as in the example chosen, it showed the importance that should be attached thereto, and also the reason why large ships gave such surprisingly good results. It was due simply to an incomplete method of calculation. One thing was certain if, omitting these corrections, the tendency had in general been to give inferior speed results, these corrections would have been made long before now.

Prof. Weighton thought it was unnecessary to convert ships to one common standard, and was in this supported by Mr. John Inglis. He could only say that he thought that both Prof. Weighton and Mr. Inglis

system facilitated the comparison between dissimilar ships, spot at once the power required, and where the corrections in question were already applied, ought to be apparent.

Prof. Weighton admitted, however, that to reduce ships to a common standard of length was of advantage in analytical investigations. So the method was admittedly analytical in character. And he (Mr. Hök) could not possibly see that any method which was not analytical in character could be of much use for estimating purposes. To him a single speed curve had little or no meaning. True, one could in an automatic fashion calculate the speed for a similar ship by its agency, but the speed curve must be brought into comparison with others by a method like Mr. Froude's or his own before it became full of life and significance. Besides the time required to convert a ship's speed curve into a model speed curve was so insignificantly small that the additional labour need not be considered.

He believed with Mr. John Inglis that the only acceptable way of estimating speeds and powers was by making use of the records obtained at progressive speed trials, and for this reason he constructed the method now brought before the Institution. He could not help thinking that Mr. Inglis' 1,000 runs would be of much more value if they were reduced to a common standard such as he (Mr. Hök) proposed.

The table of fineness and speed appended by Prof. Weighton (page 58) was not antagonistic to the table of fineness and speed given by him. Prof. Weighton's speeds for given fineness purposed to be speeds beyond which the resistance became disproportionately high; whereas to his table must be attached quite a different meaning. It was an attempt to answer a question which often perplexed the naval architect. What fineness should a ship be given which was intended to steam a certain speed? or *vice versa*, what was the maximum speed a ship of given fineness ought to be driven? To put the matter differently, if they wanted to drive a 500 feet ship 38 knots, she ought to be at least as fine as ·4; if the fineness of the 500 feet ship was ·8, her speed should not exceed 12·2 knots. Prof. Weighton, on the other hand, said that the resistances of 500 feet ships ·4 and ·8 in fineness became disproportionately high at 26·4 and 12·2 knots respectively.

He hoped that this explanation sufficed to show the different interpretation that should be put on his table and that of Prof. Weighton. But apart from this, he had not the slightest doubt himself that his own table, page 33, needed revision to some extent, and as attention had now been drawn to the matter it would in all probability soon be revised.

As the table stood the block coefficient of fineness could be approximately stated in terms of the speed by the following equation:—

$$\omega = \frac{2{\cdot}6}{V_m^{\frac{3}{2}}},$$

$$= \frac{2{\cdot}6 \times l^{\frac{1}{2}}}{V^{\frac{3}{2}}},$$

using the same notations as throughout the paper.

So, the apparently high speeds obtained by Prof. Weighton from his (Mr. Hök's) formula were approximately correct. The difficulty of attaining these speeds, however, lay in the impossibility of 500 feet ships carrying machinery powerful enough for the purpose. This was due to the fact, which he had pointed out before, that whereas the I.H.P. per ton of displacement for the 100 feet model was p_D, the I.H.P. per ton of displacement of the 500 feet ship was $p_D \sqrt{5} = 2\frac{1}{4}\, p_D$ at the corresponding speed. In order to successfully drive a 500 feet ship a speed corresponding to torpedo boat speed it would be necessary to put in reliable machinery into the 500 feet ship of $\frac{4}{9}$ths of the weight of torpedo boat machinery per I.H.P., which at the present time was an impossibility. Therefore, the speeds given in his paper could not be obtained at the present time with the present contrivances. But no doubt when further progress was made in engineering, they would not be impossible of attainment.

It might be of interest to speculate on the speeds that could be obtained by putting into ships machinery of a constant value of I.H.P. per ton of weight.

It had been shown that speeds (V) equal to $V_m \sqrt{l}$ could be obtained if the I.H.P. per ton of machinery varied as $\sqrt{l}$. What speeds (V_1) could be obtained if the I.H.P. per ton of weight of machinery was a constant?

Assuming $n = 3$, *i.e.*, power varying as the cube of the speed,

$$V_1 = V_m \times \sqrt[3]{l}.$$

The limiting value of $\frac{n-1}{2n}$ being $\frac{1}{2}$ it followed under the assumption that the weight of machinery per I.H.P. was constant that the correponding speed lay between

$$V_m \sqrt[3]{l} \text{ and } V_m \sqrt{l}$$

depending on the variation of power with speed. It lay much nearer $V_m \sqrt[3]{l}$ than $V_m \sqrt{l}$, and the former value being the smallest speed, assume it correct; then the speeds for a 500 feet boat would come out as follows if the weight of machinery per I.H.P. was assumed constant, and, of course, no retrenchment was made on carrying capacity in proportion to size, etc. :—

Speed of 100 feet Boat.	Speed of 500 feet Boat, I.H.P per Ton of Weight varying as $\sqrt{l}$.	Speed of 500 feet Boat, I.H.P. per Ton of Weight a Constant.
9	20·1	15·4
12	26·8	20·5
17	38·0	29·1
24	53·6	41·0

Now $$\frac{V_1}{V} = \frac{V_m \times l^{\frac{n-1}{2n}}}{V_m \sqrt{l}} = \frac{1}{\sqrt[2n]{l}},$$

from which it followed that, for a given value of n, the larger a ship was made the smaller was the proportion of V it could attain if the I.H.P. per ton of weight was constant. Assuming $n = 3$,

$V_1 = \cdot 891$ V for a 200 feet boat,

$V_1 = \cdot 707$ V for an 800 feet boat, etc.

From this it followed, too, that if l be given, that is, if the length of ship be fixed, the more rapid the increase of resistance with speed became, that is, the larger the value of n was, the smaller would be the reduction of speed V_1.

Say the ship was made 500 feet, and $n = 3$, $\frac{V_1}{V} = \cdot 765$.

" " $n = 6$, $\frac{V_1}{V} = \cdot 875$.

Another important matter was the discussion on the engine friction correction (μ). With regard to the curve given by Mr. Purvis, it must

be distinctly understood that it was not a curve of engine friction correction (μ), but a curve of propulsive coefficients made unity at the maximum speed. The difference in nature between these curves lay in the fact that the one was corrected for variation of propeller efficiency, and the other was not. The curve of (μ) could never take any other form than that shown in Diagram 8, Plate VIII., and had its maximum at the maximum speed. The curve of propulsive coefficients on the other hand, as shown by Mr. Purvis, had probably in many cases a maximum value at some speed below the maximum speed. But he was loath to believe that very many ships had their maximum efficiency at a speed so low as $\frac{8}{10}$ths of the maximum speed. Nor did he think that the value of the ordinate exceeded unity by so much as shown by Mr. Purvis, except in ships with exceptionally bad propellers and ships driven on trial at a speed considerably above their intended speed in ordinary working. So he was convinced that in good ships, and in ships not driven on trial above their ordinary working speed, the difference between the curve given by Mr. Purvis and his curves on Diagram 8 was nothing like the amount shown. It might or might not be so; the fact nevertheless remained that this difference showed the approximate nature of the correction, when the propeller efficiency was assumed constant at all speeds. He did not doubt that Mr. Froude and Mr. Denny could make the full correction; outsiders could not. So in the meantime they had to be content with the curve of engine friction correction; and there was really no reason why either this correction or the skin friction correction should be discarded, as Prof. Weighton, Mr. Weir, and Mr. Johnson seemed to think, because it was impossible at present to effect the far less important correction, viz., the propeller efficiency correction. The small error introduced by this omission was on the safe side—and they could incur no serious responsibility by disregarding it. On the other hand, the con-

ency curves (even exceptional ones) and the engine friction correction curves would probably be very small indeed. This view was supported by Mr. Purvis's curve if converted in the way indicated.

Mr. Young's formula for the engine friction correction (μ) would no doubt be of use to those who had not Diagram 8, Plate VIII. It must, however, be understood that the formula at its best was only an approximation of the true curve of μ. Mr. Young's formula gave a parabola set off downwards from a line drawn through the origin and making an angle of 63½ degs. with the base-line. The curves on Diagram 8 were not of a parabolic nature, and Mr. Young's formula could not represent μ for very many types of ships. The objection to his second formula stating μ in terms of I.H.P. and N.H.P. was the underlying assumption that the power varied as V^3. The only correct way of obtaining a curve of μ was to find on trial the initial friction by the method indicated in the paper (page 27), the initial friction being, besides the speed curve, the only material required for the construction of a curve of μ.

Mr. Young was quite right in assuming that the initial friction depended on the size of the engine, and not on its indicated power. Indicated power implied speed, whereas the initial friction was the friction when the speed = 0. So there could be no more connection between the I.H.P. and the initial friction than might have its origin in different construction of engines of the same size but of different maximum powers. By experimenting seven years ago on ships built by Mr. Laing it was found that the initial friction of ordinary triple expansion engines, expressed in tons, was on the average $\frac{1}{16}$th of the diameter of the low pressure cylinder, *i.e.*, for a 64 inches low pressure cylinder, 4 tons.

Mr. Sivewright understood him to advocate increase of beam for the attainment of higher speeds. This was incomplete. He advocated increase of beam with an accompanying increase of fineness. Assume constant length, draught, and displacement. Increase the breadth and decrease the coefficient of fineness (or would it not be better to say coefficient of fulness?) in the same proportion, so as to keep the displacement constant, and this change would result in an increase of speed—very little, he must admit, at speeds where the surface friction element predominated, but considerable at speeds where the wave-making element predominated. This was borne out by numerous trials, and was mentioned by the President as his experience. Here he must admit he did not understand Mr. Young's statement as to the relation between fineness, breadth, and limiting speed, and he was curious to know on what facts his reasoning was based.

Mr. Fothergill felt the want of a formula for expressing the angle of entrance and run of ships. He would give him one he had used for years, based on Kirk's analysis :—

$$\tan \theta = \frac{\psi}{1 - \phi} \times \frac{B}{2L},$$

where ψ = coefficient of fineness of midship section,
ϕ = prismatic coefficient of displacement,
B = breadth of ship,
L = length of ship,
and $\theta = \frac{1}{2}$ mean angle of entrance and run,
or roughly,
whole mean angle of entrance and run, 2θ, expressed in degrees,

$$= 55 \times \frac{\psi}{1 - \phi} \times \frac{B}{L}.$$

He had replied to Mr. Withy at West Hartlepool, but he desired to add that the ship of 5,700 tons referred to was in all probability not 400 feet long. Say she was 300 feet instead. Then $5\frac{1}{2} \times \sqrt{3} = 9\frac{1}{2}$ knots was the speed, which should not be exceeded. Mr. Withy drove her 9 knots. So his deductions were in agreement with Mr. Withy's practice.

He wished to state again most emphatically that all speeds in his paper, with one solitary exception (being the speed of 3 knots given as marking the progress in the Navy), were speeds referred to the 100 feet model. Numerous mistakes had been made by speakers through ignoring this matter. The speeds corresponding to any ship of length L were the speeds referred to throughout the paper multiplied by

$$\text{the square root of } \frac{\text{Length of ship, L}}{100}.$$

sequently, displacement was no measure of fineness, and needless to say he (Mr. Hök) never assumed or said anything to that effect in the paper.

In connection with the engine friction, when he distinctly stated in the paper that he was referring to high speed ships, Mr. Weir altered that statement into fine ships, thereby himself meaning ships of small displacement, and easily enough proved his (Mr. Hök's) conclusions to be faulty. In connection with high speed ships his (Mr. Hök's) conclusions were correct. It would no doubt be useful here to point out, and at the same time it answered an objection at the end of Mr. Weir's remarks, that it was not the fine ship which had a large value of $\frac{S_m}{D_m}$, but the ship of small displacement, which Mr. Weir would see at once by only looking at his own table. Mr. Weir also resorted to an imaginary case. Mr. McGlashan was good enough to answer him there. With regard to the comparison between ships of different types and form in the latter part of the paper, he must say that in deciding which ships showed excessive resistance due to shallow draught, and which due to large machinery, he was careful enough to compare ships having approximately equal values of $\frac{S_m}{D_m}$. So even here his own comparison was correct. Generally, if Mr. Weir would make clear to himself the distinction between a fine ship, a high speed ship, and a ship of small displacement, his remarks would appear to him in a different light.

If Mr. Sivewright had reduced the midship sections he exhibited to one unit of length of ship, as Mr. Young suggested, the comparison would have been fair; it was not so now.

Mr. McGlashan's remarks were those of a practical mind. He approved of the principle of comparison, and altogether he (Mr. Hök) was extremely obliged to him for his contribution.

He had left Mr. Froude to the last. Not only did he honour the Institution by writing a most valuable communication, but privately he had been most willing to give him assistance. He was very grateful for his communication, because it assisted him in simplifying his own method to a very great extent. One thing he regretted, that Mr. Froude did not see his way to give them also some of his valuable practical experience. With regard to the alternative method he proposed, based on the principle of comparison advocated in the paper, he (Mr. Hök) had given his reasons why he preferred his own. But, saying this, he fully agreed with Mr. Froude that "the way in which given principles of comparison are carried out are to a great extent a matter of taste."

Mr. Froude's alternative method was undoubtedly a most valuable one, and ought to commend itself to those who were used to the Admiralty coefficients.

In order to show better the different steps in both methods, he had tabulated them below side by side.

He assumed that the ship was converted into a 100 feet model in both methods, although not necessary in either. So in both cases they had to get l, $\sqrt{l}$, l^3, D_m, ω, B_m, d_m, and V_m, in order to choose the proper type model in Appendix C and value of p_D from the diagrams.

Mr. Froude's Method.	Mr. Hök's new Method.
Find $\begin{cases} D^{\frac{2}{3}}. \\ V^2. \end{cases}$	— —
,, Equivalent to—	
p_D from curves or memory.	p_D from curves.
,, Q from curves or memory.	q from curves.
,, $\Sigma = \cdot 357 + \frac{L}{60D^{\frac{1}{3}}}$.	τ from curve.
,, $Q\Sigma$.	$q\tau$.
,, $p_D + Q\Sigma$.	$p_D + q\tau$.
,, $(p_D + Q\Sigma)\, D^{\frac{2}{3}}\, V^2 = I$.	$(p_D + q\tau)\, D\sqrt{l} = I$.

The only dimensions absolutely indispensable were length and displacement. So there was no difference between the two methods in that respect.

To come finally to the discussion at Sunderland, he had answered Mr. Purvis in his previous remarks, because Mr. Purvis was kind enough to

Then, firstly, it must be quite evident to anyone reading through the paper that he (Mr. Hök) did not base his conclusion of the relative merits of single and twin-screws on the "Tripoli." But for all that he still maintained that the "Tripoli" showed markedly the inferiority of the single screw. Mr. Patterson's reasoning with regard to the "Tripoli" was simply due to an oversight on his own part. He said "they could not expect efficiency from a propeller one-third the proper size for its work." Mr. Patterson's "confusion of ideas" was that he apparently thought that the whole power of the three engines was put through the single screw when the ship was tried with only one screw. Needless to say, this was not the case. When tried with one screw, one-third of the power was developed, which was shown by the diagrams. So he (Mr. Hök) had no reason for believing that the screw was placed at a disadvantage, and must therefore keep to the conclusion arrived at in his paper. Apart from this, his reference to triple screw propulsion and guide blade propellers must not be looked upon as an attempt to settle the question of their relative efficiencies (for it must be admitted this could not be done by two solitary examples), but as an appeal to the members to give their experience of this kind of propulsion, and in this way possibly advance the matter.

A misrepresentation came next. Mr. Patterson quoted his paper to this effect:—"Mr. Hök compared Atlantic liners with Government cruisers and advocated strongly a form of ship of the 'Edgar' and 'Blenheim' type as a substitute for the present form of Atlantic liners." But in no single place in the paper did he compare Atlantic liners with Government cruisers; and the sentence wherein he, according to Mr. Patterson, "advocated strongly" a form of ship of the "Edgar" and "Blenheim" type as a substitute for the present form of Atlantic liners ran thus: "Would it be advantageous to make Atlantic liners after the model of the 'Edgar,' etc.? It is a series of problems which is recommended for the consideration of the members of this Institution." And it was because he knew that the problem could not be so simply solved as by comparing the horse-power per ton of displacement alone, and because the commercial element, strength, cost, etc., did not enter in the scope of the paper that he left all comparison out and framed his sentences in the form of a query and a recommendation. Having pointed this out, there was not much need for a further reply to Mr. Patterson's remarks on that point. However, Mr. Patterson had been good enough to show that the "Edgar" or "Blenheim" gave better performances, even if they looked at them from the point of view of equal displacements, which somewhat surprised him; and as he (Mr. Hök) had shown that

they were better if made of equal length, the problem whether ships of their form would really make good substitutes for the present liners was well worth looking into.

Mr. Patterson was right in assuming that he, when speaking of the influence of draught of water, meant I.H.P. per ton of displacement. The diagrams showed this to be his meaning. It was very probable that in other places they would find similar omissions, but anyone reading the paper intelligently could, without any difficulty, supply words which, through fear of too frequent repetition, were suppressed.

In the comparison of cargo steamers with the Admiralty designs he stated explicitly in the paper that he compared only ships of equal displacements, so Mr. Patterson's favourite figuring process was here entirely superfluous. Ship No. 92 was not of equal displacement to either Nos. 140, 129, or 125, so she was out of the reckoning altogether. No. 122 was, however, of about equal displacement to No. 125, especially if made ·8 in fineness, so these ships were directly comparable, and they most decisively supported the position he (Mr. Hök) had taken up. With regard to the conclusions he had come to respecting modern cargo steamers, he based them on more data than he had shown. To have drawn additional curves would have caused unnecessary confusion. Those omitted were, however, all very similar to those represented on the diagrams, which curves might therefore be taken as representative curves.

With regard to his alleged confusion of power due to relatively large wetted surface with power due to excessive engine friction, he had already dealt with this in his reply to Mr. Weir.

Then as to the comparison of the "Paris" and the "Umbria." If Mr. Patterson would be good enough to look up his paper, he would find

of comparison. The notion that ships could not be fairly compared unless they were reduced to the same displacement had taken very strong hold of Mr. Patterson. He would not attempt to prove that Mr. Patterson had here fallen into a grave error, but would content himself by referring to Mr. Froude's communication, where he gave his opinion of the method, for if there was any man who might be expected to exclusively uphold the method of reducing ships to the same displacement, that man was Mr. Froude. But, although approving of reducing ships to the same length Mr. Froude preferred to use as ordinates not $\frac{I}{D}$ but $\frac{I}{D^{\frac{2}{3}}}$; but, mark, not because the resistance varied as $D^{\frac{2}{3}}$, but simply in order to get rid of l in the numerator and in the expression for τ. He (Mr. Hök) had already explained why he preferred D to $D^{\frac{2}{3}}$.

The great importance Mr. Froude attached to comparing ships of equal lengths may be learned by a reference to his paper read in 1888 before the Institution of Naval Architects.

He used in his method the length constant M, which was a constant proportional to the length of ship. About it he said:—"A search among the M values for previous models will show which models correspond most nearly with the new design in the very important respect of possession of a given length for given displacement."

Another constant was the "length speed constant" L, which expressed the ratio of speed to a unit speed appropriate to length. "This value of L is also of service in comparing the results of forms which differ only in longitudinal scale, since in such cases it is a common value of L that the most nearly corresponding conditions of wave-making resistance will be developed."

This "length speed constant" was equivalent to V_m or the speed of the 100 feet model. Hence it followed that the most nearly corresponding conditions of wave-making resistance were developed at the same speeds V_m; or, in other words, all humps and hollows on the speed curves occurred at the same speeds V_m for all ships. Mr. Purvis had also pointed this out. It might be instructive to add here the hump speeds and hollow speeds for 100 feet models. (R. E. Froude, 1881.)

Hump speeds, 6·05, 6·85, 8·1, 10·45, and 18 knots.
Hollow speeds, 6·4, 7·4, 9·05, and 12·8 knots.

Mr. Froude also said: "The deeper the draught the higher are the speeds which humps and hollows occur." But within ordinary limits of draught the positions of humps and hollows did not vary much.

Mr. Froude's 1888 principle of comparison, *i.e.*, of reducing ships to equal displacement was superior to the principle of comparison he advocated, at least when the following problem had to be solved :—For given displacement and say, also draught, which was the best possible form of ship when length, breadth, and fineness could be indiscriminately varied ? But generally in practice the shipbuilder was not called upon to solve this problem, for the question of cost precluded anyone adopting the best possible form for given displacement. So the length was generally fixed beforehand, and when length was fixed he should say the principle he (Mr. Hök) advocated was the more convenient and simpler of the two. But yet Mr. Froude could more easily detect by his method whether a small variation of the adopted length would be of benefit or the contrary. This might at first sight seem a great advantage. It might therefore be useful and also interesting to investigate under what conditions any benefit would accrue from an increase of length (keeping constant displacement) and when not.

For convenience let it be asked whether an increase of length would benefit a 100 feet model,

$$\left.\begin{array}{ll}\text{the displacement of which was} & D_m \\ \text{I.H.P. per ton of displacement} & p_D \\ \text{speed} & V_m\end{array}\right\} \text{Then I.H.P.} = p_D\, D_m.$$

Lengthen the 100 feet model λ feet.

Length was then $100 + \lambda$,
Displacement D_m,
Speed V_m.

Make this $100 + \lambda$ feet model into a 100 feet model.

Then displacement was $\frac{D_m}{\ldots}$,

Call the I.H.P. per ton of displacement for the original 100 feet model $= p_D'$ at speed $\frac{V_m}{\sqrt{l}}$, and on the assumption that the I.H.P. for constant displacement varied as the nth power of the speed,

$$\frac{p_D}{p_D'} = \left(\frac{V_m}{\left(\frac{V_m}{\sqrt{l}}\right)}\right)^n = l^{\frac{n}{2}}.$$

This expression gave the value of

$$p_D' = \frac{p_D}{l^{\frac{n}{2}}}$$

at speed $\frac{V_m}{\sqrt{l}}$ of the original 100 feet model.

But the displacement of this model was D_m, whereas the displacement of the $100 + \lambda$ feet model made into a 100 feet model was $\frac{D_m}{l^3}$.

These displacements being different it was necessary to correct the rate p_D' so as to apply to the latter displacement. Assuming, then, that for constant speed the I.H.P. varied as the rth power of the displacement,

$$\frac{x}{p_D'} = \left(\frac{D_m}{\left(\frac{D_m}{l^3}\right)}\right)^{1-r} = l^{3(1-r)};$$

and hence :—

$$x = \frac{l^{3(1-r)}}{l^{\frac{n}{2}}} \times p_D,$$

and finally,

$$x\sqrt{l} = \frac{l^{3(1-r)}}{l^{\frac{1}{2}(n-1)}} \times p_D.$$

Hence it could be decided whether it was a gain to lengthen the ship by the value of

$$\frac{l^{3(1-r)}}{l^{\frac{1}{2}(n-1)}} = \delta \text{ (say)}.$$

And it was easily seen that the conditions were :—

If $\delta < 1$, gain by lengthening ;
$\delta = 1$, neither loss nor gain ;
$\delta > 1$, loss by lengthening.

Now r was generally assumed $= \frac{2}{3}$,
and δ then became $= l^{\frac{1}{2}(3-n)}$,

from which it was seen if $n = 3$, $\delta = 1$; neither gain nor loss,
$n > 3$, $\delta < 1$; gain,
$n < 3$, $\delta > 1$; loss.

So when the power varied as $D^{\frac{2}{3}}$ and the speed at a higher rate than V^3 they gained by lengthening the ship.

If r was $= 1$, *i.e.*, I.H.P. varying as the displacement,

$$\delta = \frac{1}{l^{\frac{1}{2}(n-1)}},$$

which was always less than 1 as long as $n > 1$. This was always the case in ships. Hence, if the power varied as the displacement pure and simple, there was always a gain in lengthening.

And by further studying δ it was seen that if the power varied at a higher rate than $D^{\frac{2}{3}}$, there was always a gain even if the power varied at a less rate than V^3 (the corresponding indices for V, when the indices for D were given, could easily be worked out).

Therefore, as the power almost always varied at a higher rate than V^3, and never less than $D^{\frac{2}{3}}$, they generally gained by increasing the length of ship. It was firstly at very low speeds that the power varied at a less rate than V^3, but at very low speeds the question of varying the length of ship for the sake of influencing the resistance never arose. At high speeds, on the other hand, *i.e.*, at speeds where the power varied at a higher rate than V^3, the question of increasing the length had often to be faced, but then it was always a gain except perhaps when the corresponding speed happened to fall about half-way between the humps and the following hollows, where probably the power varied at a less rate than V^3, at least if the speeds were not abnormally high. The speeds, when it was doubtful (except to Mr. Froude and Mr. Denny) whether an increase of length really benefited the ship, occurred for the 100 feet model at about 6·2, 7·1, and 8·6 knots; but as this refined treatment, which Mr. Froude and Mr. Denny alone could apply by virtue of their accurately measured

MERCANTILE MARINE ENGINEERS.

By J. R. FOTHERGILL, Vice-President.

[Read before the Institution in Newcastle-upon-Tyne on January 16th, 1894.]

Your Council having received from the Board of Trade the letter appended herewith (see Appendix A, page 156), with the intimation they would be glad to receive any observations thereon, considered, after full discussion in Council, that, as it contained matter of considerable importance, bearing upon a subject which this Institution was peculiarly well qualified to discuss, it was desirable to bring the subject before the members in general meeting, as their expressed opinions under such conditions would carry great weight and significance.

Your Council also felt that it would facilitate and promote discussion by embodying the general features of the subject in a short paper, which the writer, by request of the Council, undertook to do.

The writer fully realises the controversial nature of the proposals emanating from the Institute of Marine Engineers, and he foresees it is possible shipowners and those not directly conversant with the practical routine of the engine room, or clearly recognising the necessity for manual skill, particularly on the part of junior engineers, may misconceive the direct purport of the resolution put forth in the letter referred to, and therefore it appeared desirable to concisely review the circumstances affecting the proposed alterations conveyed in the resolution.

What are the present conditions affecting mercantile marine engineers, and how would the proposed alterations operate?

By reference to the Board of Trade Regulations (see Appendix B, page 158) it will be observed the Board of Trade grants to engineers two certificates of competency and one (extra first class) honorary. In all foreign trading steamers above 100 N.H.P. it is necessary to have two certificated engineers; but if more than two engineers are carried, it is not compulsory they should be artizans, or in fact that they should have served their time to any trade at all. Some superintendents used to prefer,

when four engineers were carried, that the fourth should be a boiler maker; and although this practice has not come into general use, it did appear to offer advantages in the earlier stages of engineering, when boilers were not constructed with the high-class tools of comparative recent date.

Some years ago it was quite common in cargo steamers when three engineers were carried for the third to be a promoted fireman or donkeyman, but as time went on owners realised the advantage in having as third a mechanic. Is it not infinitely more necessary at the present day that engineers should be trained and educated to the ever-increasing multifarious duties under their charge and responsibility?

It is to the junior engineers of the present day we must look to for our chiefs of the future.

Twelve to fifteen years ago steamers of 2,000 to 3,000 tons deadweight carrying capacity, having compound engines of 150 to 200 N.H.P., were considered large steamers, whereas at the present day these relative capacities have not only been doubled, but the demand on the knowledge and capability of the engineer has been enormously increased by the introduction of triple engines and high pressure boilers, and additional auxiliaries and economising apparatus. For instance, feed-heaters, distillers, evaporators, refrigerators, steam steering gears, steam windlasses, steam heating, electric light installation, hydraulic gears and apparatus, etc., and in addition to all these, several donkeys with their many and intricate connections to all parts of the vessel. Take a steamer of the present day, having engines of from 250 to 300 N.H.P., with the usual auxiliaries. Such a steamer occasionally carries only three engineers, and rarely if ever exceeds four. The third engineer is not always an experi-

No doubt when the Board of Trade regulations were drawn up they met the requirements of the times, but the march of progress has been rapid, and the necessities of the case demand thorough practical and technical knowledge; yet, it may be asked, does this demand upon the educational capabilities of a sea-going engineer require more than a technical knowledge, namely, a useful knowledge of the principles that govern the general working of the machinery under his charge? It must be remembered where there is a demand for scientific and high-classed education on the part of the chief engineer, or a chief engineer wishes to prove his scientific attainments, to meet such demand, he can obtain an "extra first class certificate," which is by no means an easy examination.

It is particularly in reference to applicants for appointments as junior engineers that evidence is required of their having had a technical education. This might be met by certificates granted by the Board of Trade, on a preliminary examination or an endorsement by the Board of Trade of certificates given by the committee of technical and science classes. There should be little or no excuse for apprentices not attending technical and science classes which are held during the evenings in most towns, and it is a pleasing feature to find the majority of employers appreciate the good these classes are doing and facilitate the attendance of their apprentices. Speaking from knowledge, as one of the committee of the West Hartlepool technical and science classes, I am pleased to say these classes are well attended, with most satisfactory results. Those who can afford, and are desirous of obtaining scientific attainments, can attend a course of lectures, etc., at such institutions as the Durham College of Science, Newcastle-on-Tyne.

Although we may all fully agree as to the necessity and demand for technical education, yet we must be careful not to overlook or underrate the value of a thorough practical shop training in the use of file, hammer, and chisel.

The question raised as to the term of apprenticeship really means the period or time required for an apprentice to become a proficient workman (see clauses 2 and 3, Appendix A, page 157). The old-fashioned apprenticeship of seven years became five, and we now frequently find it does not exceed four and a half or even four years. Many consider three years in the shops and two at such an institution as the Durham College of Science, Newcastle, meet all requirements. Without enquiring how far this meets the case of those who are being trained for special positions, does it meet the requirements of the engine room, where practical experience in the use of tools is so indispensable? The Board of Trade

regulations for candidates for engineers' certificates require an apprenticeship of three years in the shops or four years in an engine room at sea (see clauses *a* and *b*, par. 35, Appendix B), but it should be remembered these regulations were drawn up thirty-two years ago.

The real and growing difficulty at the present time is the gradual extinction of the all-round practical training of apprentices who are destined to become sea-going engineers. Keen competition and the growth and expansion of machinery has developed sub-division of labour and destroyed the old-fashioned plan of an apprentice going through the shops. In fact, machinemen and fitters have practically become two distinct classes. A lad on entering a shop has, in some works, the chance of going to the machines or to the vice, but, whichever he chooses, the probability is there he will remain. It is manifestly unreasonable to assume an apprentice who has served the whole or the greater part of his time at lathes and planing machines is competent to fulfil the duties of third engineer, and this is felt most severely in steamers which carry only three engineers. Take a steamer of 1,000 I.H.P., trading to India, say 60 to 70 or even 90 days, steaming on the round voyage. The average time loading and discharging during the voyage, and in which overhauling and repairs can be done is, say 14 to 18 days, and, not infrequently, much less. It can well be imagined the unfortunate state of affairs when there are only three engineers and the third a duffer, due to limited shop experience. Something is neglected or, in the majority of cases, done wrong; stoppage takes place at sea, and the anxiety and worry caused to the chief engineer is most unsatisfactory and depressing. Every superintendent knows the expense and delay caused by such incompetent men, although it is doubtful if owners are sufficiently cog-

more varied experience and are conversant with engine room requirements. Unfortunately, in the interest of these apprentices, the Board of Trade has not favoured this view (see par. 23, Appendix B, page 159), yet it is hoped the Board of Trade will now recognise that the shops associated with the large graving dock companies, although they may not build engines, are at the present day excellent training schools.

It has been suggested there is not any absolute necessity for the proposed five years' service to be during apprenticeship, although it may appear very desirable it should be during such period, and that an apprenticeship should not be less than five years, yet, if an applicant for a certificate can show he has served or worked five years in the shops and on board at repairs, etc., prior to his going to sea, it is thought to be immaterial whether service be during apprenticeship or after becoming a journeyman.

The feeling is that, if the proposed five years' service be restricted to apprenticeship, it would close the door to many proficient and experienced journeymen who might not have served a full five years' apprenticeship, although they would have served an apprenticeship acceptable in their day and the balance as journeyman to complete the requisite five years.

What is required is experience and, apparently, five years is considered the minimum time necessary to acquire that experience, but is time the only element? Should not some stipulation be made that at least, say, one-third of the time should be given to work other than that at the machines? The Board of Trade regulations recognise the value of an efficient shop training (see par. 24, Appendix B, page 160). This regulation (if it is ever put in force) should somewhat ensure proficiency in a candidate for a second class certificate, as he must make up for shop deficiency by prolonged service on board, but this does not meet the question. The contention is a junior engineer should not be appointed without substantial recognition of proficiency, and more especially so in the large majority of steamers, where only three engineers are carried. This is really the crux of the whole question, and may be summed up as follows:—The majority of steamers carry three engineers only. In such steamers the engine room requires in a junior engineer one who not only knows how work should be done, but one *who can do it.*

So far reference has been entirely made to the fitness of junior or assistant engineers in steamers carrying three engineers only, for, in the liners and larger steamers, where several junior or assistant engineers are carried, the circumstances are very different, and the want of all-round experience is not so severely felt, as each junior is under the authority of

a qualified engineer in charge of the watch, and may serve on board as junior engineer for several years before he is actually put in charge of a watch, and thus his individual responsibility is limited. The following is the engine room staff of one of the mail steamers :—1 chief engineer, 1 senior second, 2 junior seconds, 1 senior third, 5 junior thirds, 1 senior fourth, 5 junior fourths, and 3 fifths, and, in addition, 3 electricians, 2 hydraulic engineers, and 2 refrigerator men, or, in all, an engineering staff of 26 hands.

We now come to the second part of the resolution, namely, the desirability of creating a third grade certificate. The object of this proposition is set forth in the last clause of the letter (see Appendix A, page 158).

In the liners and larger steamers, where several juniors are carried, promotion is necessarily very slow, and thus a junior may serve as a junior for many years without the slightest opportunity of being eligible for a second class certificate. An eligible candidate must have served one year on regular watch, namely, he must be the engineer in charge of the watch (see par. 22, Appendix B, page 159).

It is considered if a third grade certificate be granted it would give great satisfaction and encouragement—in that it would create a position and give status to many who have to wait long for promotion. It must be remembered many of the junior or assistant engineers in the mail steamers have years of most valuable experience, and yet they are not eligible for a second class certificate until they have been for 12 months in charge of a watch, whereas a green hand out of a shop joins a steamer as third engineer in which there are only three engineers, and he is, after 12 months' sea service, eligible for a second class certificate, although, as a matter of fact, he may not have one-tenth the practical knowledge, and

The writer considered it outside the scope of his mission to take up questions other than those directly referred to in the Board of Trade letter. He therefore does not feel at liberty to touch upon the many other features as to the requirements of sea-going engineers that might with advantage be discussed, such as, for instance:—The advisableness of increasing the term of sea service of a second class engineer before being eligible for a first class certificate, etc.

It is proposed that at the termination of the discussion the President shall take (by show of hands) the opinion of the meeting on the various resolutions appended, and that the resolutions carried shall be forwarded to the Board of Trade in reply to the Board's letter.

In conclusion, the writer desires to say that he has endeavoured to treat the subject in a broad, equitable, and impartial manner, and he begs to tender his thanks to the several gentlemen who have so kindly communicated to him their views. He also begs to thank Mr. Jas. Adamson, hon. secretary of the Institute of Marine Engineers; for the copies of Mr. S. C. Sage's and Mr. T. W. Fish's papers, together with the discussion thereon, and he further desires to acknowledge the official copy of the "Regulations Relating to the Examinations of Engineers," which he has received from the Board of Trade, and from which the paragraphs, Appendix B, have been taken.

Proposed Resolutions.

1. Every person who presents himself for the first time at a shipping office to sign articles as junior or assistant engineer shall prove to the satisfaction of the shipping master by documentary evidence that he has served a five years' apprenticeship, *or not less than three years' apprenticeship and two years as journeyman*, on the making or repairing of engines, and that during at least two years of such services he shall have been engaged at "erecting" or "fitting," or "working on board steamers at the propelling machinery."

2. The above resolution leaving out that portion in italics.

3. In addition to resolution 1 or 2 (as may be voted) every person before signing articles for the first time as junior or assistant engineer shall pass a preliminary examination before the Board of Trade, or have attended technical and science (evening) classes for at least twelve months or a course of lectures at a college similar to the Durham College of Science, Newcastle.

4. That a third class certificate be granted.

ROMFORD ROAD, STRATFORD, LONDON, E.,
September, 1893.

Marine Dept., Whitehall Gardens, S.W.

the Council of the Institute of Marine Engineers, I beg to
copy of a resolution which was remitted to the Council
it might be brought to your notice, with a view to
for the consideration of the Board of Trade in the

the resolution at a recent meeting, the office-bearers
had in view all the interests involved, and deemed it
as remitted from the meeting of February 6th, before the
modification, but at the same time setting forth the
the recent meeting referred to, when the Council had

were deemed worthy of special observation, viz.:—
at a meeting of the Institute, held in the ordinary
a paper contributed by Mr. S. C. Sage on "The
Marine Engineers." The title and scope of the paper was
and the discussion extended over four evenings.
23rd and 30th, Mondays, February 6th and 13th,

desired to be conveyed, by the resolution is, that the
the mercantile marine should be as efficient as
considered that an experience extending over a
to meet the requirements.
insistence of the five years' apprenticeship is
they will be kept up and maintained.
pressions is for the maintenance of the highest
steamers, believing that only thus can we
sibility and addition to the duties devolv-
marine, as well as the engineers of Her

in the steamships, or who are steam-
such as ours to point out that the con-
while three years may have been a long
Board of Trade rules were framed
handling of tools and education in the
come when it is both expedient and
sought by the resolution.
dient and necessary that the standard
regulations, from the facts that
st on the engineers of to-day as com-

easing, and it rests largely with the
the engine department to gain the

e tool labour in our workshops now than
re reason for an extended apprenticeship.

5. It shall not be compulsory for all engineers to obtain a third class certificate.

6. All foreign-going steamships carrying four or more engineers, or in all steamships of 300 N.H.P. and upwards, the third engineer shall be a certificated engineer.

7. A candidate for a third class certificate shall have served twelve months at sea, and complied with resolutions 1 or 2 (as may be voted) and 3 (if voted).

8. A candidate for a second class certificate shall have served two years at sea instead of one as at present required.

9. Clause (*b*), par. 35 (see Appendix B), in the Board of Trade regulations be annulled.

The writer added, in conclusion, that as the paper was not written under the same conditions as an ordinary paper in that it did not embody individualism, but was written purely as a basis of discussion, in reply to the Board of Trade letter, the writer did not consider it incumbent upon him to reply to the criticism, as he took it the voting on the resolutions was the reply to the discussion. If there were any passages or expressions in the paper which did not appear clear, the writer would gladly explain them.

APPENDIX A.

BOARD OF TRADE (MARINE DEPARTMENT), LONDON, S.W.,

10th October 1892

[redacted]

(Copy) M14639.

58, ROMFORD ROAD, STRATFORD, LONDON, E.,
September, 1893.

TO THE ASSISTANT SECRETARY,
Board of Trade, Marine Dept., Whitehall Gardens, S.W.

SIR,—In the name of the Council of the Institute of Marine Engineers, I beg to bring before you the enclosed copy of a resolution which was remitted to the Council for approval, in order that the result might be brought to your notice, with a view to the subject-matter being presented for the consideration of the Board of Trade in the most approved form.

In considering the terms of the resolution at a recent meeting, the office-bearers and Council of this Institute have had in view all the interests involved, and deemed it wiser to lay the resolution, as remitted from the meeting of February 6th, before the Board without any alteration or amplification, but at the same time setting forth the points which were dealt upon at the recent meeting referred to, when the Council had the matter under consideration.

The following points were deemed worthy of special observation, viz.:—

(1) The resolution was passed at a meeting of the Institute, held in the ordinary course of business, to *read* and *discuss* a paper contributed by Mr. S. C. Sage on "The Education and Training of Marine Engineers." The title and scope of the paper was such as to evoke a good deal of interest, and the discussion extended over four evenings, the dates being Mondays, January 23rd and 30th, Mondays, February 6th and 13th, including evening of reading.

(2) The intention conveyed, or desired to be conveyed, by the resolution is, that the engineers who join, or seek to join, the mercantile marine should be as efficient as possible, and with this in view it is considered that an experience extending over a period of five years at least is necessary to meet the requirements.

(3) The object to be attained by the insistence of the five years' apprenticeship is the assurance that the standard of efficiency will be kept up and maintained.

(4) The desire at the back of these expressions is for the maintenance of the highest efficiency in the engine room staff of our steamers, believing that only thus can we expect to cope with the ever-increasing responsibility and addition to the duties devolving upon the engineers of our mercantile marine, as well as the engineers of Her Majesty's ships.

(5) In the interest of those who have shares in the steamships, or who are steamship owners, it becomes the duty of an institute such as ours to point out that the conviction is very strong among the members, that while three years may have been a long enough minimum apprenticeship when the present Board of Trade rules were framed (for exceptional lads to obtain experience in the handling of tools and education in the theory of their business), the time has more than come when it is both expedient and necessary to amend the regulations in the direction sought by the resolution.

(6) Especially should it be looked upon as expedient and necessary that the standard of efficiency should be maintained by all reasonable regulations, from the facts that—

(*a*) Greater and increasing responsibilities rest on the engineers of to-day as compared with those of the past.

(*b*) Foreign competition is greater and increasing, and it rests largely with the most intelligent use of material in the engine department to gain the advantage in the competition.

(*c*) There is less hand and more machine tool labour in our workshops now than formerly, and therefore the more reason for an extended apprenticeship.

(*d*) In our large steamers there are many young engineers who sail for years in a capacity junior to fourth engineer, and who have no opportunity for passing the examination for second engineer, but who might have granted them an opportunity of obtaining a third grade certificate as a means of encouragement.

I have the honour to be, Sir, yours faithfully,

(Signed) JAS. ADAMSON, *Hon. Secy.*

Resolution :— *6th February*, 1893.

"That, in the opinion of this meeting, it is highly necessary to amend the present regulations as to second class certificates for engineers with regard to service in the workshop, where the minimum service should be five years; and that the attention of the Board of Trade should be called to the desirability of creating a third grade certificate, which should be granted to those who have served at least five years in an engineering work, and one year at sea, and pass the prescribed examination."

The above resolution was passed at a meeting of the Institute of Marine Engineers, held in the premises of the Institute, 58, Romford Road, Stratford, E., on Monday, February 6th, 1893.

APPENDIX B.

PARAGRAPHS TAKEN FROM AN OFFICIAL COPY OF THE BOARD OF TRADE "REGULATIONS RELATING TO THE EXAMINATIONS OF ENGINEERS."

1. Under the provisions of the "Merchant Shipping Act Amendment Act, 1862," no "foreign-going steam ship," or "home trade passenger steam ship," can obtain a clearance or transire, or legally proceed to sea, from any port in the United Kingdom, unless in the case of a foreign-going steam ship of 100 nominal horse-power or upwards, the first and second engineers are certificated engineers; the first possessing a "first class engineer's certificate," and the second possessing a "second class engineer's certificate," or a certificate of the higher grade; and in the case of a foreign-going steam ship of less than 100 nominal horse-power, or a home trade passenger steam ship, the first or only engineer (as the case may be), have obtained and possess a "second class engineer's certificate," or a certificate of the higher grade.

3. The certificates of engineers are of two descriptions, viz., certificates of competency, and certificates of service; and of each description of certificate there are two grades, viz., "first class engineers' certificates" and "second class engineers' certificates." There is also the honorary certificate "extra first class."

7. Applicants will be required to produce, in addition to the usual forms of discharge, satisfactory testimonials as to sobriety, experience,

ability, and general good conduct for at least the 12 months immediately preceding the date of application to be examined, and without producing them no person will be examined. If the service has been on shore the testimonials must be signed by an employer, if at sea by the master and chief engineer.

19. Service in the engine room (afterwards referred to) for qualifying a candidate to be examined for a second class engineer's certificate must be only in those capacities which afford opportunities of obtaining practical experience as an engineer; and service in the capacity of fireman, stoker, donkeyman, greaser, winchman, labourer, engineer's steward, or any other capacity than that of engineer taking watch on engines and boilers for propelling will not be accepted.

20. Service as third and fourth engineer in foreign-going steamers, where more than three or four engineers, as the case may be, are carried, their names being all entered on the articles in their respective ratings, may be accepted equally with service as second engineer, to qualify a candidate for examination for a first class engineer's certificate, provided he has, during the whole of such service, been in possession of a second class engineer's certificate (Imperial, or under Order in Council), and provided also that he was regularly in charge of a watch. In the case of fourth engineers, however, eighteen months of such service must be proved for every twelve months required by the regulations.

21. Service in a capacity below that of fourth engineer cannot be accepted as qualifying for any class of certificate unless the testimonials of the candidate explicitly certify that during such service he has been taking regular watch in the engine room, and that the chief engineer or superintending engineer considers him properly qualified by that experience to act as chief engineer of a foreign-going steamer of 99 horse-power nominal. *In any case the applicant must prove that he has had the responsible charge of the engines or boilers on regular watch for at least twelve months of sea service, of which for not less than six months he must have been in charge of the propelling engines and rated on the articles not lower than fourth engineer.*

22. Having "responsible charge" will be understood to imply, in regard to the engines, that the applicant, for the time specified was, on regular watch, the person responsible for carrying out the orders of the engine room telegraph, and, in regard to the boilers, that he was, similarly for the period specified, the person responsible for regulating the feeds.

23. When the workshop service has been performed in a place *where steam engines are not made*, and the class of work done is similar to that

required in engine making, the service may be accepted with an additional year in the engine room; that is, three years' workshop service and two years in the engine room, of which one year must have been at sea. The approval of the Board of Trade must be obtained in every such case before the authority to receive a certificate is issued by the examiner.

24. When the workshop service has been performed in a place *where engines are made*, and the department in which the applicant has been principally engaged is not "*fitting*" or "*erecting*," if the nature of the service be such as is useful training for an engineer, the Board of Trade may, on proper representation of the circumstances see fit to accept the service as qualifying along with subsequent experience, but in every such case the applicant must prove additional engine room service as required above. The approval of the Board of Trade must likewise be obtained.

25. If a candidate has served in the engine room with a second class certificate in the capacity of a second engineer in foreign-going steam ships under 100 horse-power or in home trade passenger steam ships, which are not required by law to carry a certificated second engineer, his service may be accepted without reference to the vessel's horse-power, provided he has been on the ship's articles as second engineer, and produces certificates of discharge as second engineer, for the required period.

30. It is provided by the Merchant Shipping Act, 1854 (sec. 140), that every person who makes, or procures to be made, or assists in making, any false representation for the purpose of obtaining for himself or for any other person a certificate of competency, shall for each offence be deemed guilty of a misdemeanour,—the punishment for which is imprisonment, for any period not exceeding six months, with or without hard

(*a.*) He must have served an apprenticeship to an engineer for three years at least, and prove that during the period of his apprenticeship he has been employed on the making and repairing of engines: Or if he has not served an apprenticeship, he must prove that for not less than three years he has been employed as a journeyman mechanic in some factory or workshop on the making or repairing of engines. In either case he must also have served one year at sea in the engine room as an engineer on regular watch in the foriegn, home, or coasting trade; or

(*b.*) He must have served at least four years at sea in the engine room as an engineer on regular watch in the foreign, home, or coasting trade.

36. *First Class Engineer.*—A candidate for a first class engineer's certificate must be 22 years of age.

37. In addition to the qualification required for a second class engineer,

(*a.*) He must either possess, or be entitled to, a first class engineer's certificate of service; or, in the event of his not being so possessed or entitled, he must have served for one year at sea as second engineer in a foreign-going steam ship or a home trade passenger steam ship with a second class engineer's certificate of competency valid in the United Kingdom, or for two years at sea as second engineer with a second-class engineer's certificate of service; or having served one year at sea as second engineer with a second class engineer's certificate of service, he must show, in addition, at least six months' service as chief engineer in a vessel required by law to carry at least one engineer holding a certificate. (*See also par.* 19 *as regards service as third and fourth engineer.*)

The examiner should therefore be satisfied that an applicant for a first class engineer's certificate has not only been *in possession* of a second class certificate for the periods above stated, but that he has actually *served* for such periods in the engine room at sea, with a second class certificate, in the capacities referred to, and that his name has been entered in the articles of agreement accordingly. (*See also par.* 25.)

Examination for an Extra or Honorary Certificate.

38. *An Extra First Class Engineer's Examination* is voluntary, and is intended for such persons as wish to prove their superior qualifications, and are desirous of having certificates for the highest grade granted by the Board of Trade.

DISCUSSION.

The PRESIDENT, in inviting discussion, read the Board of Trade communication given in Appendix A, page 156, and asked members to limit the length of their speeches as much as possible.

Mr. D. ANDREW said he had perused with pleasure Mr. Fothergill's very interesting paper, and he agreed with him in many of the statements and opinions he had brought forward in favour of more competent engineers for their mercantile marine to cope with the great advance that had been made in the marine engine since the time when the Board of Trade regulations were framed for granting certificates to engineers; and that competency they were all aware must be looked for in their junior engineers and apprentices of the present time. When the Board of Trade regulations that engineers were to possess certificates were enforced, which was about the time that he (Mr. Andrew) commenced his sea-going experience, certificates of service were granted in a very liberal manner to meet the requirements of that time, and the examination for granting certificates was very much easier compared with the examinations of the present day; but he had every confidence in asserting that at that time it was the exception for a young engineer to present himself for examination who had not served a regular apprenticeship of at least five years, if not six or seven. This he had no doubt was in a great measure due to the practice then in force of binding apprentices for the above number of years; now that the indenturing of apprentices had been to a great extent abandoned a large number of their young men had taken advan-

science classes, which are held during the evenings in most towns, and it is a pleasing feature to find the majority of employers appreciate the good these classes are doing and facilitate the attendance of their apprentices." Now, he quite agreed with Mr. Fothergill, but there was a drawback to "most towns." It was not every town or city that had a College of Science, such as they possessed; therefore lads brought up in towns not possessing this useful adjunct to their education were handicapped. Again, a number of intelligent apprentices might not have the means, however small, requisite to take advantage of the facilities offered. Mr. Fothergill, after referring to the expense and delay experienced by having incompetent men to deal with, asks, "How is this difficulty to be overcome? Prolonged apprenticeship scarcely meets the case, unless a special system of training is devised by which the more capable and intelligent lads may be specially chosen for sea service and allowed a limited time in the various shop departments, and in particular it would appear advisable such lads should serve at least their last twelve months engaged in putting the machinery into new steamers, or at repairs on board old steamers, preferably a portion of their time at both." This sounded very much like limiting the supply, if lads were to be specially chosen and given a special training in the various departments. Why not extend this to all apprentices, giving each the turning and fitting, or pattern-making and fitting, or all three different branches. But the proposal that such lads should serve twelve months in putting machinery into new steamers or repairs on old steamers would certainly have a tendency to restrict the output; and the effect would be the same if preference was given to apprentices reared in the graving docks, as it was well known the numbers there were small, although he quite agreed with Mr. Fothergill that was a good school for teaching engine room requirements, but not for technical education. With regard to the proposed resolutions, No. 1 was open to objection. The part in italics should, in his opinion, be altered to read: "or not less than three years' apprenticeship and two years as an improver." An apprentice who commenced his apprenticeship when he was above the age of sixteen years was, as he understood, no longer an apprentice when he reached the age of twenty-one, and was then rated as an improver, being a grade between an apprentice and a journeyman. Again, why should an apprentice who had served, say, one year in the drawing office and then entered the pattern shop, be compelled to leave this branch, which was the hub of his technical education, after two years, to serve two years in the fitting shop, merely to learn the use of tools. With reference to the

third resolution, the nature of the preliminary examination would be defined and mastered by cramming, which, he was afraid, would leave no distinct benefit behind in the majority of cases. He was in favour of a third class certificate, as mentioned in resolutions 4, 5, 6, and 7; but in resolution 7, the age of the candidate should be fixed and proof of the same produced. He thought care should be taken in enforcing this very high standard of college and technical school training necessary for engineers, or they might be landed in the same position as the Government, and have to put on board what was known in the Navy as "engine room artificers" to do the practical work.

Mr. Tom Westgarth thought the question should be considered very carefully and deliberately, for it was a most important matter. It had been referred to them by the Board of Trade for consideration, and he thought it was fair to suppose that great weight would be attached to any reply they might send. Further, it affected a large trade, viz., that of sea-going engineers, and also a much more important body, the great trade of ship-owning and ship-sailing. With regard to the opinion of marine engineers upon this question, he took it that they need not discuss that, because the subject was brought forward by themselves, being raised by the Institute of Marine Engineers. It was more a question for shipowners, lest it should bring about a shortness of supply of engineers and lead to a raising of their value and an increase of wages. Shipowners would not contemplate that with satisfaction. Still, they had to consider the question with regard to the ultimate effect it would have upon the shipowners, and he thought Mr. Fothergill's remark that "the crux of the whole question was one of experience" was the answer

would be more useful than that of an apprentice. Another reason for adopting the resolution being that otherwise a serious injustice might be done to those now serving or out of their apprenticeship who did not happen to serve for five years. The last speaker's suggestion that apprentices should be passed through various departments of the works was no doubt a good one, but had the serious objection that it would not be profitable to employers; under ordinary circumstances if a youth was entered as a pattern maker, turner, fitter, or to any other trade, he must be kept at that trade, unless he could afford to take a less wage, or pay a small premium. As to the objection that there are not science colleges in other towns like that in Newcastle, this was not serious, because in every town where there were engine works there are also evening science classes. With regard to the third proposed resolution, he suggested that the word "evening" be omitted, and that the following words be added to the end of the resolution, viz. :—"and hold a certificate of proficiency from such class or college." It would not be sufficient for a candidate for an engineer's certificate to show that he had attended a course of study; he must also prove that he had attained a certain standard of proficiency.

Mr. M. SANDISON said Mr. Fothergill had put the various aspects of the question very fully before them and had summarised his views in a series of resolutions at the end of his paper upon which it was intended that members should vote in order that those approved might be forwarded to the Board of Trade. He would therefore express his opinion regarding these resolutions. He quite agreed with resolution 1 as it stood, and consequently resolution 2 fell to the ground. He did not approve of resolution 3. He thought it carried the technical part of a sea-going engineer's training altogether too far. He agreed with resolutions 4, 5, and 6. He also agreed with resolution 7; but it seemed to him that the latter part of the resolution was unnecessary, because before a candidate could present himself for a third class certificate, he must of necessity have fulfilled the conditions required by resolution 1. He agreed with resolutions 8 and 9. But he did not think it was necessary or desirable to send any resolutions to the Board of Trade at all. The Board of Trade, in the first place, did not ask them to present or send any resolution, but simply to express their opinion upon a resolution passed by another institution, and he hoped they would only give the Board of Trade, if they gave them anything, their opinion. He therefore thought that, instead of sending forward a series of resolutions to the Board, the gist of their communication might read as follows:—

In the opinion of this Institution, as ascertained at a General Meeting held in Newcastle-on-Tyne, January 16th, 1894, it is desirable :—

1st.—That every person who presents himself for the first time at a shipping office to sign articles as junior or assistant engineer should prove to the satisfaction of the shipping master that he has served a five years' apprenticeship, or not less than three years' apprenticeship and two years as journeyman on the making or repairing of engines, and that during at least two years of such services he was engaged at erecting or fitting, or working on board steamers at the propelling machinery.

2nd.—That a third class certificate be granted.

3rd.—That in all foreign-going steamships carrying four or more engineers, or in all steamships of 300 N.H.P. and upwards, the third engineer should be a certificated engineer, but that in other steamships it should not be compulsory for the third engineer to be a certificated engineer.

4th.—That a candidate for a third class certificate should have served twelve months at sea.

5th.—That a candidate for a second class certificate should have served two years at sea.

6th.—That clause (*b*), par. 35, in the Board of Trade regulations, be annulled.

Mr. Anthony Proud said he viewed this paper from a different standpoint than the gentlemen who had spoken. He viewed it not on behalf of the engineers, but in the interest of the apprentices. They

a great number of young men who went through their large shops were kept at one branch of the business only, and were anything but fit to go to sea. They would admit that circumstances were such that it was very easy for those young men to get to sea, but when they got there it was found that hardships had to be put on other shoulders to make up for their deficiencies. How were they to mend this? It had been suggested that they should serve the last year of their apprenticeship in putting engines on board ship. Some might suggest that they should be fitters in large shops, and the last two years be spent in the repairing shops; but the manager or masters of those shops would say that would not pay, because the very best time of the apprentices for them was just coming on, and they would lose their services when most valuable. He did not think it would be fair to the apprentices to take them in that way, and he did not think it would pay them as masters of repairing shops to take them; there were therefore difficulties in the way. He would like to see the foremen in large shops take a deeper interest in the lads who were placed under them. When he went into an engineer's shop, he invariably observed the apprentices; and it was lamentable to see the deliberate and unworkmanlike way in which some used the file, hammer, and chisel. It was only for want of being shown once how to use them, and then all would be right. Objection was taken by some to the introduction of third class certificates under the impression that if they came into force they would prove a hardship to those engineers who had only gone through a short apprenticeship. Mr. Andrew had told them of the provision made when the Board of Trade regulations were first introduced, and probably provision would be made in this case as well, so he did not think hardship would come in that way upon any of the men. He thought they ought to take time to consider this paper before coming to a decision on the matter.

Mr. D. B. Morison said that from the nature of the discussion it was evident that the subject of marine engineering at sea required ventilation, and the members of the Institutiou were indebted to Mr. Fothergill for his able and concise paper. He was of opinion that the Board of Trade regulations for sea-going engineers were dangerously behind the requirements of the times, and there was no doubt that many minor accidents and breakdowns were entirely attributable to that cause. Shipowners, as a rule, were content to rely upon the Board of Trade certificate as a guarantee of efficiency, but if they understood the true nature of the case they would realise that an engineer, although holding a Board of Trade certificate, might not necessarily be capable of performing the most

elementary duties. Take for example an apprentice in a large marine factory, who decided on becoming a turner or machineman, and who worked at small stud machines, screwing machines, or small lathes; at the end of three years he might decide to leave the factory and go to sea, and having some friend in authority, he might start as third engineer on a cargo steamer. After being a year at sea he could attend a school, and by a system of cramming be made capable of passing the Board of Trade examination. Here they had the case of a man who in the first place was allowed to take charge of machinery, but yet had no practical experience of the hammer, chisel, or file, and not necessarily even a most elementary knowledge of engines or boilers, and then by a system of cramming was enabled to pass the Board of Trade examination, and certified as capable of taking charge of machinery of the highest class. That such a case as this was possible was sufficient to show the necessity of the thirty-two-year-old regulations being brought up to date. The length of apprenticeship ought, in his opinion, to be not less than five years—three years of which could be served in a factory, and two years at a technical college. But then they got amongst a class of apprentices who were naturally industrious, and had opportunities for undergoing such a course. These men need not be considered as they were perfectly able to take care of themselves; it was rather the idle apprentice, or those whom Mr. Fothergill termed "duffers," who should be watched so as to prevent a man, who might be entirely ignorant of engines and boilers, being allowed to take charge of a watch. Fortunately, such cases as he had alluded to were not common, but they were possible, and had come under his notice. With regard to apprentices serving five years, it was very questionable whether, with the subdivision of labour which existed in large works, a lad had opportunities of becoming efficient practically in any less time, and he thought it a very good suggestion that those who were not in a position to obtain a course of training at a technical college, should be obliged to obtain certain certificates which were granted by the Science and Art Department, and at the end of the apprenticeship these certificates could be endorsed by the Board of Trade, and after the examiner had satisfied himself as to the nature of the practical work done at the factory at which the apprentice had served, a certificate of competency could be granted, and after serving one year at sea he would be eligible for a third class certificate. Mr. Fothergill also suggested that the term of probation of the second engineer should be increased, and with this he agreed; in fact, changes such as these would materially increase the efficiency of marine engineers at sea and prevent men assuming positions which they were dangerously unqualified to hold.

Mr. JAMES DYKES said his idea was that a third engineer should serve eighteen months at sea before he passed for a second engineer; the second engineer should serve two years at sea before obtaining a first class certificate. The third class certificate should be something more than a pass from even a Durham College of Science. Technical knowledge was useful to a certain extent but it was highly necessary that a sea-going engineer should know how to use his tools and have some knowledge of the machinery he had to drive. He did not see what good it would do to give a certificate to a third engineer unless he had served an apprenticeship at sea. Mr. Fothergill knew that these young engineers were sick for half the time on their first and second trips, and the donkeyman as a rule had to take their watch. These donkeymen, after serving in the engine room, often obtained a certificate, which he did not think was right and this ought to be stopped, because they had not served their time as engineers. They probably worked for 10s. or 15s. a week when the engineer was serving an apprenticeship at half-a-crown. The man should be a mechanic, and be able to use his tools. With regard to the question of serving an apprenticeship, he thought, with Mr. Proud, that the masters were at fault in the training of their apprentices. When he (Mr. Dykes) served his time he was put to fitting, turning, pattern-making, and millwright work. Now apprentices were invariably kept at the machines and lathes and had experience only in these and a slight smattering of fitting. He thought a man used to the turning lathe and machines only was not fit to serve as third engineer on board ship. In most of the engine works on the Tyne apprentices spent their time at fitting and turning, but he thought in the last year of their apprenticeship they should be working on engines on board ship.

Mr. JOHN H. BUCHANAN said, in answer to the President's request, he begged to submit his views on Mr. J. R. Fothergill's paper on "Mercantile Marine Engineers," and he had to thank Mr. Fothergill for the admirable manner in which he had carried out the task set him by the Council, and for the way in which he had arranged the leading parts of his paper for discussion. He would therefore try to follow the matter in the same order. He agreed with him that the practice of carrying a boilermaker as fourth engineer was not gaining ground, and no doubt the reason he advanced for this was the right one. Mr. Fothergill's next statement was, he thought, a most important one, viz., that owners, while at one time shipping firemen as third engineers, abandoned this practice of their own accord, and replaced the fireman by a skilled

mechanic at, of course, much higher pay. In this, as in all other matters connected with his trade, the British shipowner was of course the best judge of how to manage his own business, and he saw no reason to suppose that any section of owners underrated the importance of having competent engineers; for although, as Mr. Fothergill pointed out to them, the Board of Trade did not require skilled mechanics as juniors in the engine room, they all of them knew that owners had for years shipped such men and not labourers. So that, if the Board of Trade should think fit to forbid shipping firemen as engineers, it would be of very little importance, the practice having died out (if it ever did exist to any large extent in modern times). In the same way, if the Board of Trade determined to discontinue granting certificates to men who had not in some way learned a trade, it was quite unimportant. Few, or no such men, presented themselves as applicants for certificates, and, if they did, the examiners at the various ports had ample power to deal with them, and might, he thought, be trusted to see that the law was enforced, and to suggest to their superiors any additional safeguards which might be required to ensure the meaning of the various regulations being carried out. There did not seem to him to have been any need to trouble the officials at Whitehall about the matter. He now turned to the most difficult, and, he thought, most serious question dealt with, viz., the number of certificated engineers carried, and the means by which this number was determined; and he would here like to reverse the order in which Mr. Fothergill dealt with the various classes of steamers, also to refer to other sizes. He would take first the large passenger and cargo lines, and, like the author, he need only remark that with their large staff they were well able to make all the selection that could be wanted

obtaining excellent engineers and in rendering the services to which he alluded among the most sought after by applicants. In the steamers to which he referred, and in large numbers of others of the same power, viz., from 1,000 to 1,500 I.H.P., making voyages averaging six months, four engineers had been carried for the past twenty years or more. Of these the first and second had chief certificates, the third had always a second certificate—in many cases a chief's—and the fourth was in all cases a mechanic (in certain ships a boilermaker, but this, as they had seen, was becoming rare). It would be seen from the above that a complement far in excess of anything the law might require was not uncommon, and this was convincing proof that owners were fully alive to the importance of the engineer department, and that they found it to be their interest to regulate this department without reference strictly to the size of the vessel or power of engines, but more to the trade she might be in, and the length of the voyage. It was here that a great difficulty arose in attempting to fix by law the whole of the details of the engine room staff by the power of the engine (or, as he saw from an agreement which was made between certain owners and engineers, to fix the pay of engineers by the size of the ship). Other attempts had been made to fix the comp'ement required for trading within certain limits in addition to specifying the power, but they knew that the nominal—however it might be determined—was not a measure of the work to be done on board, at least not within a wide limit, and he had stated above that many owners found it advisable in their particular trade to carry engine room complements much in excess of what they would be required by law to do, or would probably do in other trades. There were many other factors which had to be considered when attempting to lay down a hard and fast rule for such a matter, and the law, he thought, wisely refrained from interfering further than by insisting that two of the engineers should be officers holding authority for their positions. It seemed to him that the question of the number of certificated engineers to be carried was one they should not express any opinion upon, but should leave the case of particular sizes and employments of vessels to be considered by the owners of such and their advisers, than whom there was none more able than the author of the paper now under discussion. Having referred to the engine room complement and the various conditions which determined the same in the case of vessels making fairly regular voyages, and in which four engineers were carried, he should perhaps indicate by what steps these men were selected, as it was very exceptional for the number of applicants for any opening in such steamers not to exceed the vacancies

by something like 10 to 1, or much more if the berth was known to be open, no matter what the state of trade might be. Of course, on rare occasions, emergencies would arise, but that must be so in any business, and in almost every case the appointments for next voyage were made as soon as the steamer arrived home. In the case of fourth engineers their appointment, so far as he knew, was always subject to their giving satisfaction to the chief, and in trades such as he indicated, there was opportunity for the chief to judge of his man before he was signed on, at least in nine cases out of ten. Thirds in this class of steamer were in most cases promoted fourths of the same service who had been from one to three years at sea and held second certificates, or men who had served as third in boats of smaller size. The senior appointments were hardly under consideration here. He hoped he had shown that, as far as affected steamers which did carry four or more engineers, there was little need to interfere with the owners' arrangements, and in the smaller class of boats engaged in short voyage trades, the opportunities for giving a man a trial on one run were so frequent that a selection could be made to please any reasonable chief engineer without either throwing any excessive work on him, or leading to any danger; and he understood Mr. Fothergill to say he saw no need to interfere with the state of things which had long existed with satisfactory results in the smaller class of tramp boats, any more than he did with the large lines; and he hoped they were convinced that, in employs where four engineers had been carried, there existed a most satisfactory means of training, and opportunities to qualify for promotion, without any undue responsibility being of necessity given to young hands; for although, as Mr. Fothergill stated, the third in such boats was not always an experienced man, yet in the vast proportion of

would average well over five years before they went to sea, and by far the greater number could with ease show that they had been employed in fitters' work of some sort the whole of that time, at least the lads who were at him every day for berths to go to sea, were almost without exception fitters by their own and their late employers' account at least—they could produce any amount of documentary evidence as to this—and he thought it was useless to try to restrict the entry of incompetent men by placing the matter in the hands of the shipping master. He of course agreed with the author that they must have all repairing works included, and men from these were now every week certificated, and he believed many of their best men were trained in these and at land works, where there was a heavy plant to keep in order—such as large coal pits, ironworks, or repairing shops of railways—afterwards of course working about marine engines, where for some reason they seemed soon to get the lead of men bred in marine work. He could only attribute this to the openings in marine work being more numerous and attracting the best men from other branches; and he referred to what he had noted, viz., that a large proportion of foreman and leading hands in marine shops also of the best men at sea were born and bred country men, to show how important it was that they should have free trade between one branch and another and keep open their steamers to the most pushing men of all branches as had been done in the past to the great advantage of marine engineering. As to the resolutions, he begged to state that he did not think either the proposed preliminary examination before going to sea or the recognition of mean attendance at evening classes and lectures would change the class of men who go to sea. They could now in almost every case pass any reasonable examination; in fact the great majority of the men he employed could answer the questions for second engineer before they went to sea. As to the proposed third class certificates, he thought there were so many men holding second class that there was no need of troubling with another class, but he sympathised with those engineers in large steamers who were unable to get time in to pass, and he thought the Board of Trade might allow them to be examined for all the certificates, including the extra first class, and grant them an honorary certificate till they could qualify for the actual one by service in the grades through which they had to pass in their long wait for promotion; but in speaking of this it should be remembered that they took service where they did simply because of the prospect, and were free to go elsewhere if they liked. It was not a parallel case to entering some Government service and being unable to leave without a total sacrifice of all training. In fact, this is more a case

of sentiment than anything else, but it would be a harmless thing to do to let them show they were ready for promotion when it came. He thought this question might be left to the chief examiner, who would no doubt be able to advise the Board. As to resolution No. 8, he thought the only effect of this one would be simply to reduce the number of men passing for a short time, and to give some men now holding certificates an advantage for the moment over those who were very close on their heels; but he had not seen any proof that the present law as to one year being required had led to any bad result, and he failed to see why the Board of Trade should be urged to make an alteration in the time except the members of this Institution could say of their own knowledge that one year was too short, and that two years was just long enough. Personally, he should prefer to let well alone. In practice the men were at sea on an average considerably over one year, and if the change was made they would be nearer three than two.

Mr. G. B. HUNTER said he rose with considerable diffidence to speak on the subject. He did not pretend to speak with any authority; but as he noticed all the previous speakers had been marine engineers, he thought it was right someone should speak from the point of view purely of a member of that Institution. One of the speakers thought it desirable not to overlook the interest of the apprentices as well as of the sea-going engineers. He quite agreed with that, and thought that they should not overlook the interests of the whole membership of that Institution, including particularly their Graduate members, many of whom were not serving five years in the workshops, and yet might rightly aspire to the position of marine engineers. While expressing

in the service of engines at sea and in taking charge of those engines at sea. He was bound to say that all that had been said by previous speakers as to the inefficiency of the present apprenticeship system confirmed that view; but when he asked why they could not attach any value to sea-going experience, the answer was that those going to sea received higher pay, and those who received low wages as apprentices were entitled to the prizes of the profession. That was no reason at all. It was a view entirely of the trades union order and not one that should be admitted by that Institution. He thought their object should be rather to improve the standard of education, and to give their members a fair chance of becoming intelligent and educated marine engineers. They wanted to leave the course open to any of their own sons, who were being trained as engineers, and who might not be able to spend full five years in a workshop, yet still be able to receive such a technical training as to fit them eminently for the duties of marine engineers. Apart from the consideration of their own sons, he thought they should consult the interest of their Graduate members. He did not know what the effect of the proposed resolution would be upon the prospects of those serving some of their time in the drawing office as part of their apprenticeship practice. It seemed that they would be excluded from going to sea, and if so they, as an Institution, could not give their adhesion to the resolutions. If it was so he hoped they would be so amended as to give a fair chance not only to those who worked with hammer and chisel, but those who worked as designers and draughtsmen, and who acquired theoretically and practically a thorough knowledge of marine engineering. One or two of the arguments had made an impression upon him, but not he thought in the direction intended. What Mr. Andrew professed to aim at was "a high standard of school and college training;" but how could that be attained simply by service in the workshop and at a machine? Then Mr. Morison advocated the extension of the apprenticeship from three to five years, while he said that "the apprentice's knowledge of tools consisted in working small machines only."

Mr. MORISON—That was a special case. I meant that that was a possible condition.

Mr. HUNTER—He would take it as a possibility then, but five years of such practice would not make an engineer any more than three years. Mr. Morison said not only might their knowledge consist in working small machines, but they might have "no knowledge of engines or boilers." That apprenticeship then did not further the object of Mr. Andrew, which was

"a higher standard of school and college training." Now, if the writer of the paper would pardon him, he was anxious to bring the testimony of Mr. Fothergill in support of his contention that at least they should pause and consider the matter further before they adopted the resolutions. For instance, he (Mr. Fothergill) pointed out the need of a higher training than engineers had received in the past, and that its necessity had enormously increased by the introduction of triple expansion engines, and the addition of a large number of auxiliary engines for pumping, ventilation, forced draught, electric lighting, refrigerating, etc. He (Mr. Hunter) asked them if an apprentice could gain a knowledge such as Mr. Fothergill considered necessary solely at the bench in the workshops? Where (under the present apprenticeship system) could he gain it but as a student or at sea? These statements by Mr. Fothergill, Mr. Morison, and others, had led him to the conclusion that over and above workshop training there was also a need for something higher in the way of theoretical training, which an apprentice under present conditions could not obtain, and all apprentices should be allowed the chance of obtaining the knowledge and training they needed. They must give them the chance by not compulsorily lengthening the time required for them to serve in the shops. The effect of these resolutions would be to exclude every man who had not served a long apprenticeship at the bench, yet it would be acknowledged that some of the best men in charge of marine engines had not served a regular apprenticeship. At any rate, it was not for this Institution to interpose any artificial bar to men obtaining a position in the engine room to which their ability and training entitled them unless they were absolutely bound by necessity to interpose such a barrier.

one of the best engineers he knew had only three years' shop apprenticeship, and that man could handle his tools as well as most who had handled them for five years. He thought it would be a mistake if this Institution recommended a five years' minimum apprenticeship. It was not a question of time; it depended upon the man. It was the wisdom a man had got rather than length of apprenticeship which was of importance, and unless they could discover a way of proving it better than the time test it would be better to leave it alone. He should therefore vote against all the resolutions.

Mr. THOMAS MUDD said he should like to add his voice to those of Mr. Hunter and Mr. Patterson on the side of taking a little more time to consider this matter before coming to a decision. He was the more led to recommend holding their hand a little with regard to this question, because he felt that it touched an enormous range of interests. He did not know if they had had a shipowner speaking that night, but certainly the question touched the interests of the shipowners, and there was the interest of marine engine builders, and the interest of the sea-going engineers as a body, and, particularly, the interest of the apprentices themselves; but beyond all that there was the interest of the community at large, as the safe manipulation of the machinery of our vessels at sea was involved, and therefore the question was almost a national one. They had had brought before them that night cases of young men becoming thoroughly efficient in an exceedingly short space of time, and, on the other hand, of others who after many years were still entirely inefficient. These, however, were the extremes, and he agreed with Mr. Proud that the efficiency of an engineer depended a great deal upon what there was naturally in him, and that in training engineers it was desirable to judge early of the material they had got to deal with, because if the youth had not got the right stuff in him he could never be made an engineer of, no matter how long he might be kept in the shops. He came there, however, that night disposed to vote in favour of an extended period of work of some suitable kind being done ashore before an engineer took charge of engines at sea; but, like Mr. Morison, he could not see why it should be laid down as a rule that the whole five years should be within the limits of an apprenticeship. In the works with which he was connected the rule already was that a five years' apprenticeship should be served, but he knew that in many places a less apprenticeship was allowed, and he could not see that the regulation of those establishments should be interfered with, nor that there would be any material

difference if one or two years of the five were spent in the capacity of improver or journeyman, so long as the right kind of experience was gained—that being the ultimate aim of the whole matter. On the other question, viz., that of a third certificate, he was strongly disposed to vote in favour of it. And there was another point in this connection to which none of the speakers, he believed, had yet referred, viz., as to whether the holding of a third certificate should be regarded as a necessity for those sitting for a second certificate. Since the length of service was proposed to be the same in either case he did not see very much in it, but personally he was in favour of the third certificate being required before presentation for a second certificate. This extended service at sea before getting the higher certificates he thought a most desirable matter and a much needed improvement. Much had been said by Mr. Buchanan of shipowners dealing liberally in their engine rooms, and giving a staff of engineers beyond anything laid down in any Board of Trade regulations and in accordance with their own ideas of what was desirable for the size of machinery and the voyages on which the vessels were engaged. There was, however, an obverse side to all this, and those who came much in contact with the matter would know perfectly well that they could look upon this picture and upon that. It happened to be his duty to appoint 70 or 80 engineers every year, and many present would agree with him that there was a great tendency at the present time on the part of many shipowners to appoint the least possible number of hands in the engine room. In making recommendations it was necessary to keep in mind that legislation was not for those who deal liberally and beyond all law and rule, but for those who do the opposite; and the more there was a tendency to minimise the number of engineers in a ship, the more did

he was sure other chief engineers would bear him out) gone to bed knowing that he had left the engines in charge of "a duffer," and it was very fortunate that he had not been called to explain it before a Board of Trade enquiry, because he should have been told he had no right to go to bed. Whether there should be more time served in the shops or more time served in the engine room, he would not say; but he could say this, there was certainly room for more experience. Speaking of the cargo steamer, his experience was rather ancient, but he must confess there were only three engineers, and very often only two. But speaking of mail steamers, there was an injustice at the present time with the Board of Trade examination. He knew of many good men who had not been able to get a ticket for seven or eight years, and who during that time had grown so rusty that they had great difficulty in passing. He thought a third certificate desirable. Treating of apprentices put them back upon the commercial aspect, and if not practicable commercially it was not possible anyway. Mr. Fothergill wished him to mention the complement for one engine room, that of the "City of Paris" mentioned in his paper. They had a chief engineer (himself), a senior second and 2 junior second engineers, a senior third and 5 junior thirds, a senior fourth and 5 junior fourths, 3 fifth engineers, 3 electricians, 2 hydraulic engineers, 2 refrigerator men, 33 greasers, 3 store-keepers, 3 donkeymen, 54 firemen, and 57 trimmers.

A MEMBER—How many "duffers?"

Mr. GEARING said he could tell them that at least six, for on going aboard one of the liners he had to tell six not to present themselves at table to sign articles.

Mr. W. KILVINGTON said that it appeared to him that it would be very difficult to get any opinion expressed on this question from the meeting as a body, as so many individuals seemed to have such different views. He agreed with Mr. Hunter, and seconded very earnestly his request, that very serious consideration should be given to the subject before any report should be sent to the Board of Trade as coming from this Institution. The most important practical point in the resolutions submitted by Mr. Fothergill seemed to him to be that requiring two years' service at sea before a second certificate could be obtained. Most engineers would never present themselves for the new "third" certificate, of course, at all, but would have to be two years at sea before they could get the second. That was the only resolution, he thought, that was any

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893–94.

PROCEEDINGS.

SPECIAL GENERAL MEETING, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, JANUARY 30TH, 1894.

F. C. MARSHALL, ESQ., PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle, on January 16th, 1894, which were approved by the members present, and signed by the Past-President.

The PAST-PRESIDENT explained to the meeting that he had taken the place of the President (Mr. Robt. Thompson), who was laid up with an attack of influenza.

The meeting having been convened for the special purpose of further discussing Mr. J. R. Fothergill's paper on the "Mercantile Marine Engineers" question, submitted by the Board of Trade, the Past-President called upon the SECRETARY (Mr. Duckitt) to read the following communications :—

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MERCANTILE MARINE ENGINEERS.

79, MARK LANE, LONDON,

DEAR MR. DUCKITT, *January* 12*th*, 1894.

Mr. Fothergill's excellent paper on "Mercantile Marine Engineers" scarcely goes as far as I for one would like to see it go. I am of opinion that the whole of the regulations of the Board of Trade require to be thoroughly revised and be brought, so to speak, up to date.

In the first place, I am strongly of opinion that five years' apprenticeship is none too long before allowing an engineer to sign articles, but I would qualify this by allowing not less than three of those years to have been served before the age of twenty-one is reached, the remaining two years could be either in the shops, drawing office, or technical school; and further, that an apprenticeship in a ship and engine repairing establishment should count as equal to time spent in an engine factory. For my part I have found the lads trained in the factories of our mail companies better men by far than those trained in large engineering establishments, on account, no doubt, of the facilities they enjoy of becoming thoroughly acquainted with the machinery on the ships as well as those repairs required in the shops.

My next point is that on no consideration whatever should a donkeyman be allowed to be carried in the place of an engineer: this can easily be avoided if the shipping master see the last discharge, or if the applicant has not been to sea before, then the certificate from the employer where the apprenticeship was served.

Following on this I would suggest that no engineer be examined for a third grade certificate (and which I think would be very desirable) until he had served at least two years at sea. I purposely make the additional year because I think it would raise the status of the engineer, and it would prevent a lot of almost boys from obtaining the certificates of the higher grades. Thus the age of the third grade engineer would at least be twenty-three years as a minimum. To obtain the second grade certificate he must serve at least two years again, thus bringing his age to twenty-five years, and after two years as a third engineer where more than three are carried, he would be allowed to pass for the first grade certificate.

Thus the minimum age of the chief engineer would be twenty-seven years. I know many will object to these proposals, as it is difficult to deal with present cases. I would say with regard to this that the third grade certificates should be issued to all engineers below the rank of third engineer, and who have been to sea the requisite period, without reference to their apprenticeship, on a written and *viva voca* examination of about a standard equal to what was required of a second engineer in 1862, when the examinations were started; that the second grade certificates be issued to those engineers who have qualified for them under the existing regulations, until, say a period of twelve months from the date of the alterations of the regulations, and a similar course for those of chief engineer. At the end of that period the new regulations would come in force, and all time would be counted as I have stated above.

One point which the author does not refer to, is that the Board of Trade might issue to all apprentices, whether engineers or otherwise, on the completion of their apprenticeship, a certificate which would show at a glance that the holder had served his time, where he had served it, and for how long.

With reference to the resolutions, I agree, as I have already stated, to Nos. 1 and 2, so far as that I would leave out the words in italics, but I would add that three years must have been completed before twenty-one years of age.

No. 3.—I do not agree with this, but leave it in the hands of the superintending engineer to decide.

No. 4.—I agree with this.

No. 5.—I do not agree with this, as the third grade certificate should always be the stepping stone to that of the second grade.

representing a piston speed in feet per minute, and divide by 1,700, this would equal the I.H.P.

Thus:—

$$\frac{C \times 550}{1{,}700} = \text{I.H.P.}$$

and

$$\frac{\text{I.H.P.}}{5} = \text{N.H.P.}$$

I beg to add my quota of thanks to Mr. Fothergill for his very excellent paper, and for the vast amount of information he has afforded the Institution, and I hope the discussion will lead to a satisfactory solution.

Yours faithfully,

WALTER PHILLIPS.

30, SIDE, NEWCASTLE-ON-TYNE,

DEAR MR. DUCKITT, *January* 13*th*, 1894.

I regret that a previous engagement will prevent me attending on Tuesday night, when the question of the third engineer's certificate will come up for discussion, but in compliance with your request, I beg to lay before you my views upon the proposal. I quite approve of it, and I concur with the stipulation that the candidate should serve five years in the shops and perform one year's sea service before he is eligible for the third class certificate. The interests of the shipowners must not, however, be overlooked, and I would suggest that steamers over the power that carry three engineers, and steamers under the power that carry two engineers only, should continue to sail as they do at present with one uncertificated engineer, otherwise it does not appear where candidates for the third engineer certificates are to be trained, except in the case of steamers carrying four engineers.

The one year of preliminary sea service might be dispensed with, but as the object of the Institute of Marine Engineers is to raise the standard of the sea-going engineers, I think it would be against this policy to do so, nor should it be granted unless he has attained the age of twenty-two years. I should further advise that every candidate for a second class certificate should have two years' sea service, with a third class certificate, and every candidate for a first class certificate should have at least two years' sea service with a second class certificate.

The stipulation requiring a five years' apprenticeship might be relaxed in those cases where lads have attended a technical school.

Yours faithfully,

WM. MENZIES.

81, GRACECHURCH STREET, LONDON,

DEAR MR. DUCKITT, *January* 13*th*, 1894.

I have to thank you for a copy of Mr. Fothergill's paper which is to be read before the Institution on the 16th inst. I much regret that business engagements will prevent my being present on that occasion.

The subject of Mr. Fothergill's paper—the training of engineers for service in the mercantile marine—is of the very greatest importance, not only to marine engineers themselves, but to the community at large.

The only way in which this country can expect to maintain her present mercantile position among the nations of the world is by the excellence of her ships and their machinery.

With Mr. Fothergill's paper before us it will be also well to remember, that whatever courses of training the Board of Trade now decides upon as necessary before obtaining their various certificates of competency, will, in all probability, remain in force for a number of years.

It is more than thirty years since the Board of Trade framed its present rules, and, from one's experience of Government departments, it is more than likely that the amended rules will be made to serve for an equally long period.

I quite agree with Mr. Fothergill that a five years' course of training in an engine factory is necessary, and I also agree with him that two out of these five years might be served as a journeyman. I would also add that one or two of these five years might, at option, be served in the drawing office.

It is when the young engineer has finished his shop training and enters upon his sea service that the weakness of the present system becomes apparent. The bulk of these young engineers commence their

and that after a few months' experience a green hand often becomes a very useful man.

That may be so; but so long as the Board of Trade rules allow an inexperienced man to undertake responsible duties, those rules are not fulfilling their object.

What is really wanted is twelve months' sea service before taking a responsible position on board ship at all. He should also have to pass a proper examination as assistant engineer before taking charge of a watch in any ocean-going vessel at all. I cannot see that N.H.P. has anything to do with the question. The examination for a certificate as assistant engineer should be based upon such courses of study as are taught in our technical schools and colleges; should comprise as its subjects pure and applied mechanics, physical science, machine construction and drawing, and workshop practice; and the questions should be taken from a published list of text-books. It should be the examination of an engineer's life, only to be passed by long and careful study.

Having obtained this certificate, the young engineer would be qualified to take charge of a watch, either as second or third engineer. Two years of such service should qualify him as a candidate for a first class certificate. I would abolish the present second class certificate as useless. It is not wanted. Two of the engineers in every vessel should have first class certificates. Under the present system, a third engineer with a second class certificate cannot obtain his first class unless four or more engineers are carried.

The examination for a first class certificate I would have to comprise the practical and theoretical working of an engine, practical up-keep and repair of every detail of marine machinery and boilers, use of the indicator, the making of working drawings, book-keeping, and the expenditure of stores, etc.

A simple recapitulation of previously-learned mathematics is of no use. The chief engineer's examination should comprise such subjects as enter into his daily work.

The extra first class examination I would not alter, but the holder of it should have the option of entering the Royal Naval Reserve as engineer with a good retaining fee.

To summarise the above, a marine engineer's training should, in my opinion, consist of:—

Five years' apprenticeship in a marine engine factory (or at option three years' apprenticeship and two years as journeyman—in either case one or two years in the drawing office at option).

One year sea service as junior engineer, followed by examination and certificate of competency as assistant engineer.

Two years at sea as assistant engineer, followed by examination and certificate of competency as first class or chief engineer.

I may add that most shipowners would gladly give place on their vessels to one or even two junior engineers instead of that present necessary evil, the donkeyman.

Trusting that the importance of the subject may be my excuse for so long a letter.

Yours faithfully,

HERBERT M. ROGERS.

LIVERPOOL,

DEAR MR. DUCKITT, *January* 15*th*, 1894.

I am very much obliged for the opportunity you give me of expressing my views on the subject of Mr. J. R. Fothergill's paper, and I much regret that my engagements will not permit me to take part personally in the discussion I feel sure his excellent paper will provoke.

It is almost unnecessary to remark, that as an old sea-going engineer in days gone by, who has been on both sides of the hedge that divides the ocean tramp from the mail steamer, the subject Mr. Fothergill deals with so ably is fraught with the greatest interest to me, as it must be to hundreds of others who, like myself, have a lively recollection of breakdowns at sea, with more or less (as it happened to turn out) competent assistants to assist in the repairs.

After all has been said and done, it is under these circumstances that the true value of the sea-going engineer can be most correctly assessed,

by the sea-going fraternity and derisively alluded to as a "gentleman engineer," but with the gradual introduction of more complicated apparatus and machinery (without which the steamer of to-day is considered more or less incomplete) the necessity for an amount of technical intelligence on the part of the men in charge of them has slowly but surely killed that prejudice, and the fear now is that we may rush to the other extreme, and so get technical knowledge at the expense of practice and experience.

There can, I think, be no two opinions that the engine room of a steamship is not the proper place for a man to serve his apprenticeship in, though there is equally no doubt that however capable a mechanic a man may be before he joins his vessel, he will still find he has a good deal to learn when he gets there, and with a view of minimising this lack of that information, which is of greatest value, as much as possible, I would make five years the minimum term of apprenticeship in an engine works, two-thirds of that period having been devoted to work other than that done by machines, and require twelve months' service in the engine room before admitting a candidate as eligible to pass an examination as third class engineer, or as an alternative, at his option, two years' service at sea to qualify him to pass an examination entitling him to a second class certificate.

I find my letter has run to a greater length already than I had intended, and in closing it I would like to add that I am entirely in favour of resolutions 2, 4, 5, 6, 7, 8, and 9, and desire nothing more than to hear in the near future that Messrs. the Board of Trade have decided to make them indispensable conditions.

Yours faithfully,

CHRIS. GEDDES.

NEWCASTLE-UPON-TYNE,

DEAR MR. DUCKITT, *January* 15*th*, 1894.

In reply to your circular letter of the 10th inst., I much regret that I shall be unable to attend the meeting on Tuesday, but may I say that although whatever my friend (Mr. Fothergill) writes must be well worth hearing, yet I trust the Council of our Institution will reflect seriously before they send any resolution whatever to the Board of Trade.

Ours is a scientific society, and if we express any opinion as to the extent to which the Government should control shipowners we are entering upon the domain of politics and upon ground which is highly debateable.

Further, the question whether or not a man may learn engineering by a definite apprenticeship or otherwise, whether (to put it in another way) a man should be debarred from becoming an engineer from the fact of his not having devoted a certain time between the ages of, say, fifteen and twenty-two to the study of his craft, raises a question which is dear to trade unionists, and is in my humble opinion still further removed from the sphere of our Institution.

You will remember that when it was suggested that we might utilise the commodious rooms of the Employers' Association the Council decided that the mere appearance even of being mixed up with trade questions should be avoided.

Will you kindly bring these considerations before our President, and, if he approves, you are welcome to read this letter to the meeting.

Yours faithfully,

WIGHAM RICHARDSON.

BALTIC CHAMBERS, NEWCASTLE-ON-TYNE,

DEAR MR. DUCKITT, *January* 16*th*, 1894.

I am sorry I cannot be present at your meeting this evening, but quite endorse Mr. Fothergill's views, provided any alteration of the present regulations does not affect either chief, second, or third engineers who have been at sea previous to any such alterations coming into force. I think this is fairly due to our present engineers.

Yours faithfully,

WM. COOPER.

NEWCASTLE,

but he has never been at sea before. The vessel leaves Liverpool or some port in the Bristol Channel, gets into dirty weather at once, the third engineer, even allowing he is not sea-sick, has no practice in the routine of keeping a watch, and the whole of the work for the first two days at least falls on the first and second engineers, who either have to take six-hour watches, or four hours on and four hours off. I do not think this is good for the shipowner, or for anyone on board; it certainly is not conducive to the safety of the vessel.

My own opinion is that all engineers before being allowed to take charge of a watch at sea ought to serve at least six months as assistant engineer.

This is the case at the present time in the Austro-Hungarian monarchy, and I find from my own experience that it works well for the shipowners, who practically get the services of a mechanic on board for very little more than his board and accommodation. In the company I belong to we pay them £2 per month—this is the highest paid, it being in fact a six months' apprenticeship. It is good for the mechanic, because it teaches him the routine of the watch, and makes him more independent, and for the safety of the vessel and the comfort of the other two men on board it certainly is better. By carrying out this plan no third certificate would be required; the third certificate in the proposed resolution is optional, and is only of use where four engineers are carried, and in some cases at least would deter owners from carrying a fourth engineer. In the case of the assistant, many owners would carry one, where they now only carry three engineers, as they would get an extra mechanic on board for very little.

In regard to the mail boats, or vessels carrying more than four engineers, I think that on the juniors showing, by documentary evidence, that they have served two years in the engine and boiler room on regular watches, that they ought to be allowed to pass for second, and also that the words in paragraph 21, Appendix B, printed in italics, should be annulled.

There is another matter in regard to resolution 1; it practically debars all mechanics who are not engaged in the making or repairing of engines.

Now, I think there are none who would contend that the apprentice who served in the erecting shop of any of the large marine engineering establishments, and who got every part of the engine from the machines, practically so far finished that he had only to line it in place, and mark the bolt holes, would be a better mechanic than the man who had served in a small machine or general engineering shop, where in many cases he

had to use the hammer and chisel, file, etc., in place of the machine. Whom do you think is more likely to have the all-round training of which Mr. Fothergill speaks? What about our millwright apprentices who can use any tool that is required? On the other hand, we certainly do not wish to see a stone-maker or a bicycle-maker in charge of the engines, but I consider that a resolution could be devised to stop that.

Mr. Fothergill also states that there are other questions which he does not feel at liberty to touch upon, which might be discussed with advantage to engineers. I would say that now we are at it, let us have the matter thoroughly thrashed out, and not be always given to tinkering.

There is the question of the home trade cargo boats, steam trawlers, tugs, etc., these may be of any size, and however large, are not obliged by law to carry an engineer of any sort: this should certainly be alluded to. My opinion is, that in all vessels under the British flag in the home trade, or going out and in to ports of the United Kingdom, not being under the denomination of a passenger ship, as mentioned by the Board of Trade, with engines of 40 N.H.P. or above, carrying one or more engineers, the first or only engineer, as may be, should be obliged before signing articles to produce Board of Trade discharges to show that he has served two years at sea in the engine room: this to include the six months as assistant, this to interfere in no way with the persons presently in charge of these vessels, who can show by discharges or other documents that they have served in the engine room on watch for a period of two years. Some might say, what of those under 40 N.H.P.? well, they will at least get an engineer who has been six months at sea, if the above is carried.

There are also other matters, such as how and under which circumstances, trade, and size of engines and boilers, three, four, or five

Resolution 2.—Every person presenting himself to sign articles as an engineer to take responsible charge of a watch in the engine room or boiler room of any vessel must prove by Board of Trade discharges that he has served as assistant engineer at sea, on watch in the engine room for six months, besides complying with the conditions contained in Resolution 1.

Resolution 3.—Same as No. 2, with the addition of Mr. Fothergill's No. 3 resolution.

Resolution 4.—Same as No. 8 in Mr. Fothergill's paper, but to include the six months at sea as assistant.

Resolution 5.—Same as Mr. Fothergill's No. 9.

Resolution 6.—Annul paragraphs 23 and 24, Appendix B, as too indistinct. Resolution No. 1 in this list covers both.

Yours faithfully,

A. ROLLAND.

DEAR MR. DUCKITT *January* 17*th*, 1894.

I think Mr. Fothergill's paper embraces nearly all the alterations to the Board of Trade rules necessary to ensure the safe working of the machinery of our ocean steamers.

I am of opinion that a radical change is required, and that Mr. Fothergill deserves the Institution's hearty thanks for the able manner in which he has brought the matter forward. I will now offer you my ideas for what they are worth, as in my opinion these Board of Trade rules ought to be altered, and I think something approaching the following conditions should be observed to ensure a good reliable test for sea-going engineers before getting their Board of Trade certificates.

A young man before being allowed to sign on any ship's articles should have worked at the trade of engine building and repairing for at least five complete years, say three years in the turning, fitting, or erecting of marine engines, and on board of ship; and to make it more open I would say two more years as either journeymen or apprentice in the pattern shop, smith's shop, drawing office, or boiler yard of any engineering works, and that it shall not be compulsory to be continuous service. A certificate of this service to be produced before a youth is allowed to sign on for the first time.

After a year's service at sea as junior engineer in any position he should be qualified to pass for a third's certificate, which would entitle him to go third of any vessel afloat, or second of any vessel under 250 N.H.P. A second year's service at sea would qualify a man to pass for a

second class certificate, which would entitle him to go second of any vessel afloat, or chief of any vessel under 250 N.H.P.; and a third year's service at sea would qualify him to pass for a chief engineer's certificate, which would entitle him to go chief engineer of any vessel afloat. If the Board of Trade rules were altered to something near this I am sure it would work most satisfactorily to both owners and to sea-going engineers, and it would ensure the owners getting a better class of men to start at sea as junior engineers, and make it fair to juniors in large mail vessels, and altogether would ensure a more reliable engine room staff being placed in our ocean-going steamers than under the present system.

Yours faithfully,

T. CARTER.

Mr. W. DALRYMPLE continued the discussion, and said he was of opinion that no person should be allowed to take charge of a watch in an engine room who had not passed an examination for a third class certificate, this certificate to be granted when the examiner had satisfactory proofs that the candidate had served not less than three years before he was twenty-one in a shop where engines were made, and two years as journeyman fitter or erector (not turner nor machinist), and where, in the opinion of the examiner, he could have sufficient practical experience in the making or repairing of engines to enable him to take his share of work in case of breakdown and in the ordinary repairs of a marine engine. Twelve months' service with a third class certificate to be required before being examined for second class, and two years' service before being granted a chief engineer's certificate. From some experience in appointing engineers he thought the Board of Trade would be justified in refusing to allow a

Mr. W. STAFFORD said they must not forget that this was a question more particularly between shipowners and their engineers, than between this Institution and the Board of Trade. While they were asked to give an expression of opinion on the points raised they ought to be particularly careful that they did not commit themselves to any series of resolutions which might hamper the shipowner by making it more difficult for him to man his engine room, and at the same time prove of very questionable advantage to those junior engineers who were seeking to enter the ranks by making that entrance more difficult. This would undoubtedly be the case if they decided, and their decision was adopted, that it was necessary for a junior engineer to pass a preliminary examination before being allowed to sign on for the first time. He was afraid that in the discussion thus far too much stress had been laid on the teaching obtained in technical and science classes as a means of preparation for a youth to take his place in the engine room, not that he would in the least depreciate the immense value of this class of education when gained in addition to a proper and thorough apprenticeship; but that it should be taken in lieu of an apprenticeship or of any part of an apprenticeship, or that it should be made compulsory on a youth before he was allowed to enter the engine room as a junior engineer, were propositions which he thought this Institution ought not for one moment to entertain. On the contrary, he quite agreed with the writer of the paper, where he said: "this is really the crux of the whole question, and may be summed up as follows:—The majority of steamers carry three engineers only, in such steamers the engine room requires in a junior engineer one who not only knows how work should be done, but one who can do it." This knowledge and this ability they all knew could not be obtained in the science class or in the college, but must of necessity be got by years of apprenticeship in the shops. It was perfectly true, as was stated in the last night's discussion on the paper, that the question of fitness of their junior engineers to go to sea was a question very much in the hands of their foremen and managers of works, more in their hands, in fact, than in anyone else's, except, of course, the lads themselves; and if their foremen and managers could only bring themselves to give a little more attention and consideration to the needs of those lads who intended going to sea by moving them about in the shops and outside, and putting them on such jobs along with men who would further their education in that direction, they would themselves be benefited in the long run by having in a little while a number of young fellows able to turn their hands to anything, and almost, if not quite, as

good as men of thorough practical experience; in addition to which would be the satisfaction of turning them out as journeyman a credit to themselves and to the works in which they were brought up. It could not be denied that there was something very unsatisfactory in the regulations governing the admission of junior engineers on board, and it was also unquestionable that it was upon the chief engineers of the boats already mentioned—those carrying three engineers—that this pressed most heavily. For instance, a lad who had had a good education and was fit to pass any examination almost, was sent into the shops for a year or two to learn the trade, he might be attentive or he might not, but before he had fairly looked round, his time was up and he knew little or nothing of shop work. His friends, by influence, got him pitchforked as third on board a steamer carrying three engineers, and she sailed on a thirty days' voyage, they were hardly well outside before the chief found out what a prize he had on board, the lad absolutely knew nothing and was totally unfit to be left on watch, and the result was that the chief and second had to arrange to go on 6 hour watches for the voyage, before the end of which, it was needless to say, they were pretty well tired of it; and, of course, if bad weather was encountered the evil was accentuated. Such a state of things ought, of course, to be rendered impossible; and this brought him to the only point on which he thought they, as an Institution, ought to give an expression of opinion, and to his mind that opinion was well and fully expressed in the first of the proposed resolutions appended to the paper. He would suggest that his resolution in its entirety be sent as the opinion of the Institution, and if anything further were necessary they should recommend that no person be permitted to sail as third engineer on board a steamer carrying three

examination, to ship as an assistant engineer and take his watch at sea under the guidance of the chief engineer. He served in this capacity for a period extending from one to two years. He was then advanced to the position of a marine engineer, and took a watch. When he had arrived at this stage, he (Mr. Gravell) would consider him fit to pass an examination for second class engineer, and to begin his sea-going career. In his experience he had found many sea-going engineers who had learnt more in two years at sea in the way of using hammer, chisel, and file, than during the whole of their apprenticeship. The reason for this, he thought, was that they had been more closely watched by their superior officers, and therefore took more pride in their work. Besides, a feeling of responsibility was put upon them, and this always had a tendency to sharpen anyone. He was therefore of opinion that an apprentice who had the qualifications as stated, and had served two years as an assistant engineer—he meant by this that he should not be allowed to take a watch before he had served two years' apprenticeship at sea—and had a good character given him by those under whom he had served, if found capable of advancement, would be qualified to go and pass his examination, either as third engineer or for a second class certificate, as was enforced at present; but until he had fulfilled these offices he should not consider him fit to be entrusted with the charge of a watch.

Mr. D. Myles thought the question was for superintending engineers more than anybody else.

The Past-President (Mr. F. C. Marshall) said they were so small a number that it would be unfair and unreasonable if they should pass any vote as expressing the sentiments of that Institution. It seemed to him that the only course they could pursue was to adopt the motion that was brought forward at their last meeting, that the matter be referred back to the Council to take what action they thought best. They were much indebted to Mr. Fothergill for the admirable paper he had written on the subject, however much they might agree or disagree with his views. As regarded the whole subject there should be no question that they needed to take every means to secure the efficiency of their engine room staff. Hitherto they had practically left it in the hands of the Board of Trade, and the regulations they issued in 1862 had been the rule since for the appointment of engineers, and he was not quite sure that the regulations of that date had not worked out as well almost as they could wish. The examinations of

the Board of Trade had produced on the whole a race of engineers that had carried their mercantile marine up to the high position to which it had now attained. And whether the increase of certification was necessary or worth considering, he thought the lines upon which they had gone formerly should be pretty well adhered to. He quite agreed with Mr. Gravell that it was desirable that a lad should pass an examination before he was allowed to take charge at sea, and that he should not go straight out of the shops and take a watch. Something should be done to give him the required experience which he could not get in the workshop, even with five years' apprenticeship. They had generally little knowledge of the pulling to pieces and putting together again of machinery. That could only be obtained by erecting engines on board, in the first instance, then repairing engines, and going to sea. The general tenor of the discussion seemed to be that there should be some extended experience before a young man went to sea. He would, however, point out that all his experience was not obtained in the erecting and repairing of engines in the shops: it was gained at sea. The question had been thoroughly thrashed out, and it was unnecessary for him to add to the discussion. He suggested that someone should move that the question be remitted to the Council.

Mr. A. Proud—Would you give us your views with regard to the time a second engineer should serve before receiving his first class certificate?

Mr. J. R. Fothergill—The circular letter does not refer to the question of chief engineers at all.

a vote was not to be taken he wished to say one or two words. He regretted there was not a large meeting, as he thought it would have been very much better to have taken a vote on each resolution, or amendment, as might have been proposed. However, under the circumstances he felt with the Past-President, that due to the few members present it would be unreasonable to take a vote, as such vote could not carry weight as representing the opinion of the Institution, and therefore he agreed it would be better to refer the question back to the Council. Some objection had been taken to this Institution taking up the matter at all. He failed to take that view, for it appeared to him, if an Institution, composed as they were, and embodying the principal marine engineers on the North-East Coast and many in other parts of the kingdom, thoroughly conversant with the subject, would not express their opinion in reply to the Board of Trade invitation, he failed to see whom the Board of Trade should refer. Then it had been said the whole question was one of unionism. That he considered was due to a misconception of the subject and a prejudiced conclusion without careful consideration of the paper. He thought the remarks of several of the speakers wandered wide of the paper as representing the subject of the Board of Trade letter. For instance, much had been said on the subject of apprenticeship, but from his point of view, although the training of a sea-going engineer must necessarily run in parallel lines with the apprenticeship question, yet it was not entirely one of apprenticeship. He took it the service of apprenticeship (and those managers of works who had spoken considered five years desirable) was necessary to train and educate a lad so that when he became a journeyman at twenty-one years of age he was competent and qualified to do journeyman's work and worth journeyman's pay, but so far as a junior engineer was concerned they cared not whether he was twenty-four or thirty; what they wanted was evidence of five years' service, not necessarily as an apprentice, and that part of that service had been at marine work, and thus he was in favour of the first resolution as it stood. It was all very well for some managers of works to say they had no difficulty with the junior engineers they appointed, but they had the pick of their apprentices and the leavings were left to superintending engineers to utilise as they could. The first resolution was not intended, as some thought, to debar an apprentice serving his time in works other than the making of marine engines, but what it did insist upon was, that for at least two years prior to joining a steamer a junior engineer should have been engaged at "erecting" or "fitting" or "working on board steamers at the propelling machinery." He again emphatically repeated what was wanted in a

junior engineer joining a steamer and more especially so when only three engineers were carried, was: One who not only knows how work should be done, but one who can do it. He must say he was pleased to find and had been much struck by the consensus of opinion of all those speakers who had a real and practical knowledge of what was required of an engineer at sea. Almost without exception they were in favour of a more extended and varied practical training of apprentices destined to become sea-going engineers. In conclusion, he thanked the meeting for the manner in which his paper had been received. He had done his best to be fair and impartial, and he felt flattered by the discussion that had taken place.

Mr. M. SANDISON moved the resolution proposed by Mr. J. C. Stirzaker at the last meeting, viz.:—"That this meeting having discussed the able paper read by Mr. Fothergill, authorises the Council to draw up a reply to the letter received from the Marine Department of the Board of Trade," which was seconded by Mr. H. B. BUCKLAND, and carried.

The meeting then dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893-94.

PROCEEDINGS.

FIFTH GENERAL MEETING OF THE SESSION, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, FEBRUARY 13TH, 1894.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Special General Meeting, held in Newcastle-upon-Tyne, on January 30th, 1894, which were approved by the members present, and signed by the President.

The discussion on Mr. Frank Caws's paper "On Certain Principles of Motion, as taught by the Pendulum; and as illustrated by the Resistance of Ships and other bodies moving through Fluids; together with a brief sketch of the Pendulum Speed-Power Meter" was opened and adjourned.

Mr. HUGH MACOLL read a paper by Mr. William Bell "On a New System of Construction for Large Vessels of Cellular Type." The discussion was opened and adjourned.

DISCUSSION ON MR. FRANK CAWS'S PAPER ON "CERTAIN PRINCIPLES OF MOTION, AS TAUGHT BY THE PENDULUM," ETC.

Mr. J. KING opened the discussion on Mr. Frank Caws's paper by remarking that the subject was one well worthy of discussion by that Institution. Although he had not much faith in ship model speed experiments of any kind giving practical results, yet this beautifully lucid paper of Mr. Caws was based upon a very simple application of well-known mechanical principles, and was deserving of careful examination and criticism by shipbuilders. The part of the paper most concerning the subject of speed models was that relating to the resisted pendulum. A difficulty one had at the outset in considering this proposed method of measuring a ship's resistance was that the model, at every instance of its stroke, was varying in its velocity, and at first sight that would seem not quite a parallel case to the ship moving at a constant speed. Mr. Caws had been careful to make it clear that the full speed which he took for his model was that of the vertex speed due to the angle of starting of the pendulum—not the mean speed, but the *theoretical vertex speed* of the pendulum. It was quite evident that in these experiments the model did *not* attain the theoretical vertex or full speed due to the momentum of the pendulum, but reached its maximum speed some distance on the initial side of the geometric vertex. If they supposed a pendulum starting at 10 degs. and ending at 9 degs. on the other side of the vertex, it seemed as if the true speed should be taken as represented by 9½ degs. and not 10 degs. But on proof, that assumption would appear to be wrong, for models might be made with sufficient resistance in themselves so that when they passed the vertex they might have a very small speed and yet the model resistance should be measured by the total energy put into the model in the initial part of the swing. Therefore the corresponding speed at which the model was running should be taken as that due to the initial angle of the pendulum. Speaking of the law of corresponding speeds, it was pleasant to note that Mr. Caws had given Reech credit for being the first propounder of the law. This part of the subject could be more clearly expressed by a graphic method which he might put on the board.

Diagram No. 1 was practically a reproduction of Mr. Caws's own diagram, with A, the position of the plumb bob at the initial part of the stroke ; Z, where it would reach if unresisted ; C, the point of maximum speed ; and

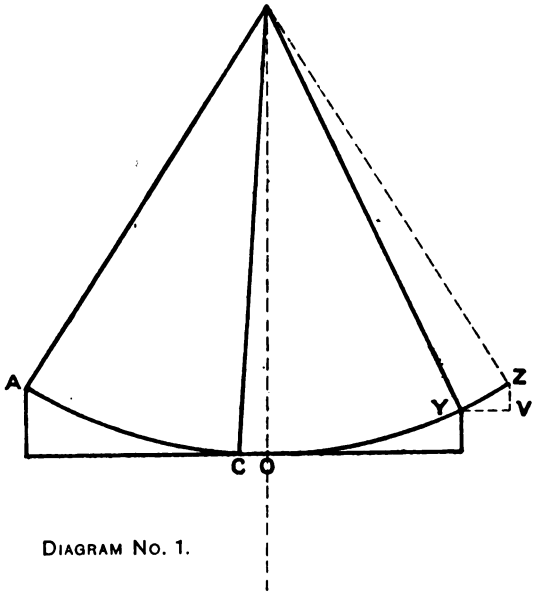

DIAGRAM No. 1.

Y the final position when it was propelling the ship model. The energies expended during the vibration were represented in Diagram No. 2.

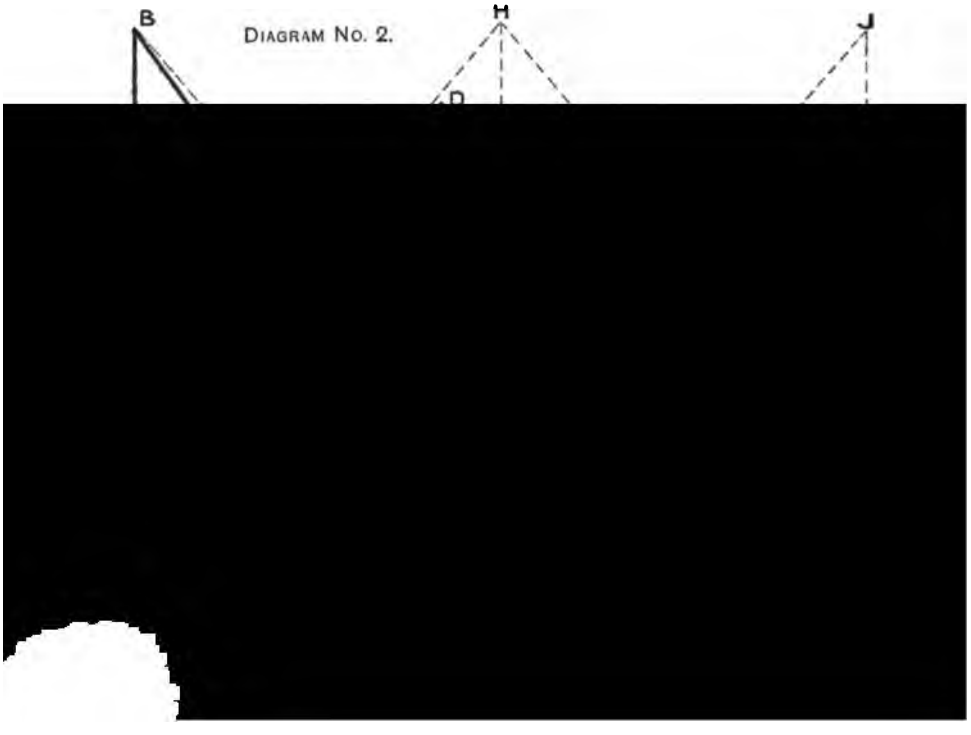

DIAGRAM No. 2.

beginning of the beat, B C the line of potential energy in the initial half of the beat; the potential energy disappeared before the pendulum reached the theoretical vertex point O. C G was the line of potential energy in the final half of the beat, A D Y the line of kinetic energy throughout the beat, A B, A H, O J, and A H Z were the corresponding lines of the unresisted beat, A L represented the line of expenditure of total energy or work done during the beat, and J X = J Z — G Y = Y L. That was to say, Y L represented the difference between the energy put into the model at beginning of beat and the energy recovered from the model during the final part of the vibration. From this it was clear then that the expenditure of energy or rate of doing work which went on throughout the whole of the beat, went on at a constant ratio along the line A L, the ordinates to this line representing the amount of energy which had been expended, or work done up to that particular point of the stroke. So that although the model was moving at a continually varying velocity, yet the result, or the loss of energy which was represented by Y L, was really

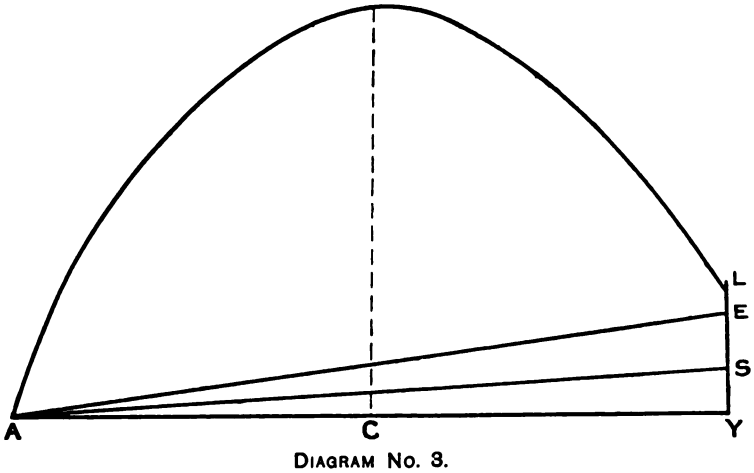

DIAGRAM No. 3.

equivalent to the loss of energy as though the model was travelling at a continuous speed. This was evident, because the velocity of the model was due to the *conversion* of potential into kinetic energy, and was proportional to the amount of kinetic energy developed; but as the conversion went on in a constant ratio the true relative speed might be considered to be in a constant ratio to the total potential or kinetic energy put into the model. So that although apparently the model was varying every instant in speed, yet the amount of energy expended upon the model was constant, and being so, the speed might be considered constant, and at the full real vertex speed. The energy absorbed in the driving of the model during the

the circle. No force whatever was due to the motion, so that kinetic force had no existence. Mr. Caws also said that the arc of swing represented the time and speed of the swing. Now, if the time were taken as constant for all arcs of swing, then the length of the arc would represent its speed for different angles of swing. This is approximately true for the unresisted pendulum, for he had calculated that for very small swings the time was 2·42 seconds, while for a swing of 60 degs. the time was 2·46 seconds. But if the arc represented the speed it could not represent the time which was nearly the same, whether the swing was large or small. Again, if the pendulum was resisted the time of swing would no longer be the same for all sizes of swing, so that then the arc would not represent the speed. Mr. King had referred already to the variation of the speed during the swing. This varying speed was of very great importance in considering the fluid resistances introduced against the moving body. These resistances varied enormously with the speed, and he did not see how it was possible to compare the results obtained at a speed always varying and those got at a uniform speed. Mr. Caws met this objection as to the speed always varying by regarding the velocity of the pendulum as having a constant value, which might be partly potential and partly kinetic. Now, motion was not something which could be stored up and made potential. It was the rate at which a body was changing its position from one place to another. A body might either be moving or at rest, but it could not store up its motion for future use. The speed must be either actual or non-existent at a particular instant. To speak of kinetic speed was the same thing as to say speed of motion. This division into potential and kinetic speed had no real basis, and we were bound to recognise that the speed at the beginning of the motion

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1·57 : 1, so that there was some mistake in reckoning it as double. Again, Mr. Caws says: "For the same measure of energy, = E, which will turn the mass of, say, a pendulum, or wheel, or cylinder, about a stationary centre at a mean speed of A O Y per beat (*i.e.*, per half revolution) will roll that pendulum bob, wheel or cylinder along a level floor, free of ties, at the continual vertex speed = 2 × A O Y per half revolution; because in the latter case there is no fixed centre to absorb by reaction half the energy, $= \frac{E}{2}$; and so the whole energy, = E, is devoted to the momentum of the rolling mass." Now, this was incorrect. A fixed frictionless axis of revolution absorbs no energy. The idea seemed to be this:—

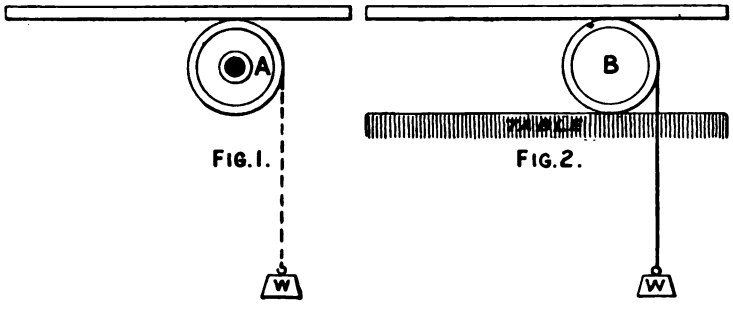

FIG. 1. FIG. 2.

If in Fig. 1 the weight descended the horizontal bar resting on the top of the wheel would move at the same rate as the falling weight. In Fig. 2, where the wheel did not turn about an axis but rolled along the table, the speed of the horizontal bar on the top of the wheel would be double that of the falling weight. Now, the error lay in assuming that after falling, say 2 feet, the speed of the falling weight would be the same in the two cases. In reality, if the two horizontal bars were the same weight, this speed would be greater in Fig. 1 than in Fig. 2, and the kinetic energy would be exactly the same in the two cases. No energy was therefore absorbed by the fixed centre, so that the analogy which Mr. Caws drew between the effect of fluid resistance and that of a fixed centre was based on a fallacy. These were some typical instances of the dynamical errors throughout the paper which it was impossible to allow to pass unquestioned. In the discussion of the effect of the resistance on model attached to pendulum bob there were many points as to which statements were made which seemed to him incorrect, and certainly required proof.

As to the application of the pendulum to ship models and their resistance, he did not pretend to deal with that, but he would doubt very much the value of resistances obtained at speeds constantly varying, when it was certain that the resistance varied very much when the speed was altered, and to base conclusions on such results might be very misleading. This pendulum meter might possibly be of value in comparing two different models under exactly the same conditions, but as to the possibility of arriving at the power necessary to drive a given vessel at a given speed from the results of such experiments he would have very great doubts.

Mr. JAS. THOMSON said that what he had intended to say with reference to the dynamical explanations had already been said by Mr. Ferrier. Without going into these elementary explanations, he wished to say that in his opinion Mr. Caws's argument was based upon a fallacy—really on two fallacies. The first was the assumption that there was in any sense a constant velocity in the case of the motion of a pendulum. They could attach a definite meaning to the terms "kinetic" and "potential" energy, but they could not understand "potential" or "kinetic force," or "potential" or "kinetic velocity." Now, he thought that by the use of the terms "kinetic" and "potential velocity" Mr. Caws was led into the assumption that there is in some sense a constant velocity in pendulum motion. Another difficulty was this—in considering the resistance of ships what was wanted practically was resistance of the ship at some given speed, that was to say, a ship was ordinarily intended not to start and stop, but to run for a number of days at approximately one speed. What they wanted to know was the resistance at that speed. Even if they could measure exactly the resistance at varying speeds it would be of

to bring out was this: they could not trust with any certainty calculations based upon model experiments when those experiments were dependent upon those two assumptions, first, that there is in any sense constant speed in pendulum motion; and secondly, that there is anything that can be described as a real wave attendant upon a model attached to the pendulum as described.

Mr. J. DENHOLM YOUNG said that those who had spoken upon the paper had done so from a mathematical point of view; and he was sorry that they were not more hopeful about the case; but one of the facts that faced them was that Mr. Caws had obtained results which compared very remarkably with the actual speed curves of the vessels. It augured well at least for future successes with his apparatus. He could not endorse Mr. Caws's system of dynamics; he was rather compelled to agree in principle with what Mr. Ferrier and Mr. Thomson said, and those who based their dynamics upon Sir Isaac Newton's teaching, would be bound to follow in that respect. He was sure, however, that a great deal might be learned from the pendulum meter. Those who had seen that beautiful instrument would recognise the immense labour Mr. Caws had spent over it—labour he thought scarcely equalled throughout the country—and deserving of the highest recognition for painstaking and careful research. However, all had disagreed with Mr. Caws's method of calculation, and some had come to the conclusion that it was impossible to arrive at any real result from the experiments with a model in a pendulum meter. He (Mr. Young) ventured to suggest that it was possible to arrive at approximately correct results by a different line of thought. It appeared to him that when the model started from her leash that she started with a low velocity and small resistance. As her speed increased her resistance also increased (it might not be by a fair curve), until the maximum velocity was attained, and then decreased again, and what they registered upon the meter at the end of the beat was a quantity represented by an area bounded by a curve. What they wanted to find out was something approaching the ratio of mean height to vertex height in this curve. They should have registered exactly the same amount had the area been of a rectangular form, and knowing the mean length they could at once have found the mean height; but the difficulty now was to find the vertex height. They knew the vertex speed. Now, suppose they assumed that the velocity on one beat varied nearly as $\sqrt{\text{versine}}$, then the resistance varied nearly as the versed sine of the angle swept through at any instant of the beat. By a

certain process of calculation not very difficult to perform, they could obtain the required ratio which might be approximately expressed as =

$$\int_{0}^{\frac{\pi}{n}} \frac{\dfrac{\text{versine}\ \theta\ d\ \theta}{\frac{\pi}{n}}}{\text{versine}\ \theta} .$$

Mr. Caws's pendulum had a great advantage over the travelling truck, in the absence of all internal friction, and it was possible that the error introduced in a calculation of this sort would be comparatively small if properly carried through. He hoped that, owing to the extreme delicacy of Mr. Caws's experiments, something really useful in the cause of practical science might be obtained from the tank before them.

Mr. E. W. De Rusett said that Mr. Caws's experiments were quite as accurate as any he had seen produced from any other system of model experiments. Some of the models of vessels built by Messrs. C. S. Swan & Hunter had been tested by this meter, and latterly the curves came out satisfactorily. Mr. Caws had been a long time engaged in this work, and, of course, like other men, he had had much to learn, especially as his system was so novel. He thought they should have much patience with a gentleman who had given so much time to experimental research, and extend to him every encouragement in solving the difficult problem he had undertaken and which had entailed such an amount of hard work. Whatever may be the differences of opinion as to the laws governing the speed and power curves obtained from the author's meter, there remained the fact that the curves themselves were of the same character as those

more likely to give the most correct indication of resistance, and hence become the standard for comparison? Was there a standard in the sea progressive speed curves, when the data upon which they were constructed was, to say the least, sometimes so unreliable? For instance, the speed had been proved to be materially affected by the depth of water, also by the tide with its changing velocity, by currents, by direction and force of the wind, and by the extent of tophamper, etc., besides the indicated power would be affected by the indicator, by grit, priming, etc., making the piston work stiffly, also by inherent defects in the instrument—defects well known to the thinking men present. That the cards did vary, and that high or low powers might be selected according to circumstances increased the difficulty. Another very important factor in the relation between effective and indicated powers was the relative newness of the engines, the condition of the packing, and last but not least the screw propeller, and who could anticipate what proportion this would absorb of the expected power? Now, in the pendulum meter there was no current, the water was relatively deep, there was no wind, no screw and no vibration, and the indicator was very simple and constant. So, taking all things into consideration, it seemed hardly credible that the meter could be so wrong in principle as to be even as unreliable and variable as the progressive speed curves of actual ships—which so few seemed to question —and when compared to which, model speed curves were too hastily pronounced erroneous when any marked difference existed between them. Now that the meter had been improved and more experience gained in its operation, the later model experiments were very encouraging; and no doubt was left on his mind that when progressive speed trials were more exhaustively analysed and proper allowances made for the disturbing elements referred to, an effective and reliable ratio curve would be produced, by which the effective power of the meter would be readily translated into indicated power. He had known Mr. Caws as a patient, hard working investigator for a good many years, and he thought that instead of throwing their mathematics at him they should give encouragement, and he believed they would soon be able to acknowledge the value of his pendulum and ship resistance meter.

The PRESIDENT said he had submitted a model to Mr. Caws within the last few days, and the facts which had come out at the speed trials made it look very promising for shipbuilders. The speed curve Mr. Caws gave from the model was very similar to the actual results. He thought his tank would be very useful, at any rate to show what was the best shaped

model for a good speed, as a basis to work from. If they could introduce it, it would be much less costly than the Government tank or Messrs. Denny's tank at Dumbarton.

Mr. H. MACOLL said, like Mr. De Rusett, he had been interested in these tank experiments for some time. In some of Mr. Caws's early experiments with small models, the results, especially when made in a tank having a close resemblance to an ordinary house bath, did not at first impress the speaker very favourably. However, after some slight inaccuracies were remedied, and later, and more particularly since the new tank had been constructed, he considered the problem of ship's resistance had entered on a very interesting and instructing stage. Although there was a very considerable difference between the curves given out for different vessels; still, it was undeniable that these curves as given out by the meter gave a quite proportionate curve to that ascertained by the graduated trial of the ship at sea. He did not by any means pin himself to the mathematical deductions by the inventor of the tank arrangement. His own opinion was, it would have been better for Mr. Caws to have gone straight for the practical application and adaptation of his scheme to full sized vessels. One thing, however, which occurred to him, and which he observed was overlooked by those who treated the matter from the purely mathematical aspect, was that the energy or momentum imparted to the model during the first half of the beat was partly restored by the model during the second half. So that they had the problem of a restricted or retarded pendulum during the first half of the beat, and an accelerated or assisted pendulum during the second half. That was easily proved by experimenting with the pendulum if placed at the aft side of the trunnions or guides instead

obtained by the expenditure of more power than was expected, and the higher part of the curve did not correspond in the ship and model trials. However, after some time the propeller, which had four portable blades, was removed, and a new one having solid blades fitted gave about $\frac{3}{8}$ths of a knot more at extreme speed, and thus brought both curves into fair comparison with each other. Dealing with cargo boats pure and simple they entered on more reliable ground, and he had a strong impression that a considerable proportion of the discrepancies they found at low speeds was due to taking the indicator diagrams with too stiff springs. The springs should be altered so as to give nearly as much, if not more, area than the area swept at high speeds, as a very slight want of appreciation of the pressure made a large difference in the power given out. Another matter, by the way, would also be a great convenience if at slow speeds a half knot course instead of one knot could be run, the time now necessary to steady the engines, and also the ship would be largely reduced. The probable effect of smooth *versus* rough models had been alluded to. Full experiments had been made with models of varying degrees of roughness, and somehow the water was so very accommodating that the rough models slipped through the water nicely and gave almost exactly the same results as the smooth ones. It appeared to him the problem only required the hearty co-operation of shipbuilders and engineers to extend the range of experiments with different vessels and at varying speeds, and the results would be a more exact understanding of the questions and also the prediction of the necessary I.H.P. for a given speed with a given model.

The discussion was adjourned.

ON A NEW SYSTEM OF CONSTRUCTION FOR LARGE VESSELS OF CELLULAR TYPE.

By WILLIAM BELL.

[Read before the Institution in Newcastle-upon-Tyne, 13th February, 1894.]

While merchant steamers were small, of fine form, and without structural complication, there was little scope for improvement in the details of construction, but with the advent of large full vessels of cellular type the mechanical conditions have altered, and modifications, formerly of little or no economic value, can now be introduced with advantage.

The long, straight, middle body and deep floors and holds of modern steamers permit at least a partial application of the principles and manipulative methods developed in bridge building where the "lattice" has displaced the solid form for deep girders, and economy and exactness of workmanship result from a multiplication of interchangeable parts.

Vessels of the dimensions now general require great longitudinal strength. The modifications of structure required for the carriage of water ballast give this in excess to the bottom, and hence, below the bilge in cellular vessels longitudinal framing is of little or no structural use. Above the bilge, however, it is clear that an arrangement of the framework, or part of it, in a longitudinal direction would prove beneficial to the structure as a whole.*

These considerations gave rise to the constructive scheme now to be described, which is an attempt to take advantage of existing conditions, and to produce a kind of girder formation and arrangement more suitable for large steamers and more economical than the system in vogue.

* In riveted structures subjected to stresses varying in force and direction the practical value of the attachment of the several parts is not the ultimate shearing resistance of the rivets, but the power of resistance to movement in the joints. This power will be increased by increasing the frictional resistance of the riveted surfaces.

For the purpose of comparison the midship section of a merchant steamer of cellular construction, recently built to Lloyd's highest class, has been selected (see Plate XVI.) and another section prepared for the same vessel on the new principle (Plate XVII.). By comparing the two sections the points of difference may be easily discerned. This steamer is of the following dimensions:—Length, 360 feet; beam, 44 feet 6 inches; depth (moulded), 29 feet. She has a continuous double bottom, slab keel, and solid plate floors. In lieu of web frames in the holds the frames are increased in depth to 9 inches, and supplemented by three heavy side keelsons projecting 15 inches inside the reverse bars. This arrangement was adopted to secure greater stowage capacity.

In the modified section the scantlings of the framework are arranged so that the collective strength (considered as beams) of any set of girders in a given length shall not be less than the collective strength of the corresponding set in the section to Lloyd's rules. The principal structural modifications are as follows:—

Keel.

The keel (see Plate XVII.) is formed of two bulb angles of special design, about 8 inches by 8 inches by $1\frac{1}{8}$ inches, which take the place of the "slabs" on each side of the vertical centre through plate, and thus dispense with them and with flanged keel plates. These angles run fore and aft as far as they can be conveniently bevelled, beyond which the present arrangement is resumed. This modification will increase the lateral strength of the keel, remove all difficulty in securing good workmanship, now considerable, and cost much less than the present combination of "slabs" and flanged plates.

floors, riveted to the fore and aft flanges of the T steel struts by three $\frac{7}{8}$ inch rivets at each end. This arrangement of floor forms, in effect, a modified "lattice" beam. It can be made of equal strength to the solid plate floor, perforated with manholes, with a saving of about 20 per cent. in material. The platers' work will be done in less than half the time and with one-third of the help required to manipulate the plate floor, and the riveting will be reduced by 25 per cent. Against local strains this floor would be more efficient than the plate floor.

In the writer's experience where damage to the bottom of cellular vessels has been sustained the light bottom angle connecting the floor plate to the skin is the first to give way. The rivets sheer and the bar is forced up, thus destroying the efficiency of the girder before the power in resisting distortion, due to its depth, has been exerted. In the modified floor there are no rivets to sheer except those in the struts, where the rivets are concentrated, all in double sheer, and not to be affected until the liner between the struts has been crushed up. Another advantage with this form of floor would be that, if damaged, it can be more easily and cheaply repaired than the present floor.

This floor may be modified in various ways, and strengthened for very large vessels, by substituting for the liners between the struts triangular bracket plates, connected at the top and bottom to the heavy steel angles, thus forming, without any waste of material, diamond-shaped openings between the struts. The finished floor (see Plate XVIII.) will then resemble in appearance, though not in character, the bracket arrangement formerly in use, but, unlike the latter, it can be riveted before going into place, like an ordinary floor. Outside the tank the floors are formed by splitting the channel steel side frames, and bringing the upper flange and part of the web to the floor height, the space between the severed parts being made good by a flanged plate for connection with the tank side. In this way the inner flange of the channel steel, in way of the floor, where useless, is made to serve as the upper flange of the floor.

Side Frames.

To the upper turn of bilge, along the line of the first longitudinal, the side frames are spaced 26 inches apart. Above this point the spacing increases to 52 inches, every other frame being omitted. These frames are formed of channel steel 12 inches by $3\frac{1}{2}$ inches by $\frac{8}{20}$ inch, and are supplemented by longitudinal frames spaced vertically 30 inches apart. The longitudinals all run parallel to the deck sheer, and the shell plates, which are 5 feet wide, in way of them, and fitted edge to edge, butt on

alternate longitudinals, and are riveted to them with a horizontal seam, butt strap outside. From the keel to the bilge the shell plates are fitted in the usual way with overlapping edges. The longitudinals in way of the shell plate edges are formed of intermediate pieces of T or angle steel, 16 inches by 7 inches by $\frac{8}{20}$ inch, fitted between the vertical frames, and attached to them by lug pieces. These lugs are of angle steel $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{8}{20}$ inch on the back side of the frame, and $6\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{8}{20}$ inch on the flange side. By this means, without shaping, the intermediate pieces are connected to either side of the channel frame with equal facility. To the inner edges of the intermediate pieces two continuous bulb angles 4 inches by $3\frac{1}{2}$ inches by $\frac{10}{20}$ inch are fitted back to back and riveted to them and to the inner flanges of the vertical frames. These bulb angles form the inner "boom" of the side longitudinal girder. The outer boom is formed by the shell plating and horizontal seam butt strap.

The longitudinals running between the plate edges, along the centre of the shell plates, are formed in the same manner, only the intermediate pieces are of angle steel, 16 inches by $3\frac{1}{2}$ inches by $\frac{8}{20}$ inch. Where the longitudinal crosses the vertical butts of the shell, however, intermediate pieces of T steel are introduced to increase the rivet attachment in way of the butt. The structural effect of this formation is to produce a series of interlacing girders of nearly uniform strength in every direction, all in equally intimate contact with the shell plating. The area of unstiffened plating is the same all over the side, and nowhere greater than at present. The vertical frames have efficient lateral support at close and regular intervals, and cannot buckle under stress. A considerable addition is made to the longitudinal strength of the vessel without increase of

longitudinals. When building on this plan, the construction of the bottom and tank might proceed as usual, but when erecting the side framing a commencement would be made amidships, and go on simultaneously forward and aft. The bulb angles, intermediates, and joint pieces for the several longitudinals, all exactly alike, and requiring no distinguishing marks of any kind, would be ranged conveniently on each side of the tank top, ready for hoisting into place, when a few of the vertical frames are on end and secured. The lug pieces would, of course, be riveted to the frames before erection. As soon as the longitudinals are in position, and well bolted together, the beams will come in without adjustment, and the whole side will be perfectly fair, and keep so, without the constant attention now necessary to secure even approximate fairness of side. In this way constructive operations will be greatly facilitated and much labour saved.

By means of a simple contrivance, designed for the purpose, the greater part of the longitudinal framing will be riveted in place by hydraulic machines at one-third the cost now incurred for inside work of similar description. The templates from which the frames and longitudinals are prepared are very simple, easily applied, and so designed that it is almost impossible to go wrong when using them. The sheer heights and centres of the longitudinals must be correctly drawn on the board. The *modus operandi* is as follows:—The vertical side frame is set unpunched, laid on the board, and brought to the scrieve mark. The cross frame template is made to fit into the bosom and over the two flanges of the channel steel frame bar, and contains in correct relation to each other the two landing holes, the three lug piece holes, and the two holes through the inside flange for the longitudinal bulb angles. Thus, when any of these holes are right the remaining holes must be right also. This template is now laid on the frame and its centre made to coincide with the board centre of a longitudinal. The seven holes are marked in the usual way, and the template is shifted on to the next longitudinal and so on until all are marked. The distance between the centres of the landing holes and the centres of the holes for the bulb angles being the same the same template serves for both sides of the vessel. The only possible mistake that can be made in applying it is in coinciding the template centre with the board centre. To check this a ribbon template is used, containing the landing holes and the remainder of the shell holes through the frame between the landings. This is applied to the outside of the frame and shows at a glance whether the cross template was correctly

placed in each case. Another template, similar to that for the longitudinals, gives the correct position of the beam end holes.

For the preparation of the several parts forming the longitudinal framing four universal templates are employed, each containing all the holes for the separate piece in correct relation to each other and to the holes in the frame templates. One of these templates serves for all the lug pieces, another for all the intermediates, a third for the bulb angles, and the fourth and last for the joint pieces of the bulb angle butts. By means of these seven templates the whole of the side framing, horizontal and vertical, for more than half the length in full vessels is produced with far greater exactness than is possible by the present method of marking everything separately for its own place after the frames are up and faired, and at much less expense.

Towards the ends of the vessel, where the shape changes rapidly, the longitudinals would have to be made from moulds prepared in the loft, or the longitudinals might be partly omitted at the ends and closer vertical framing substituted. Should the longitudinal framing be carried all fore and aft the vertical frames would then be bevelled to the top of the floors, from which point they would be twisted so as to stand square to the curvature of the side. By this means waste of material in shaping the intermediate pieces would be avoided and labour saved.

It is probable that many of the shell plates and the horizontal seam butt straps can be produced from templates in the same way as the longitudinals before the vessel is framed; but even should all the plates be templated in the usual way there would still be an advantage in this arrangement of framing as regards the fitting of long plates, for they could be templated and punched in much less time than is now required,

Beams.

The beams are made of channel steel, 12 inches by $3\frac{1}{2}$ inches by $\frac{11}{20}$ inch, supplemented by two longitudinals of the same size and description as those for the sides and produced from the same templates. These longitudinals are intended to give lateral support to the beams, to assist the decks in resisting compressive strains and to increase their longitudinal strength. The beam ends are secured to the frames by eight $\frac{7}{8}$ inch rivets, and by lug pieces riveted to the frames and lower flanges of the beams. This attachment is thought sufficient without adding knees, which break up stowage and are at best of doubtful structural use in vessels having numerous transverse bulkheads. The bulkhead must be the most effectual element in resisting change of transverse form and the first to be affected by the action of racking strains. To assist the bulkheads and to compensate for the absence of beam knees it is proposed to fit one or more strong partial bulkheads in each hold between the present transverse bulkheads.

Stringer Plates.

The stringer plates are not brought to the shell by cutting pieces out of the plate in way of the frames as the practice now is, but are fitted in line with the inner flanges of the frames. The connection between the stringer plates and the shell plating is effected by intermediate angles, 16 inches by $3\frac{1}{2}$ inches, of the same thickness as the stringer plate, fitted on the under side between the frames and riveted to the stringer plate by the row of rivets in the stringer bar. These angles are also connected to the frames at one end by a lug piece, and at the other by the beam flange. In this way waste of material is avoided and labour saved, while the value of the attachment between the stringer plate and the shell is in no way impaired. This mode of fitting the stringer plates has been recently adopted by an eminent Scotch shipbuilding firm with complete success.

Bulkheads.

The bulkhead frame (see Plate XVIII.) is of channel steel, the same as for the other frames, with a narrow rim of plating riveted to it between each of the longitudinals. To this rim, which projects about $3\frac{1}{2}$ inches clear of the bulb angles, the plating forming the body of the bulkhead is attached. There is a gap in the rim opposite each longitudinal to allow the bars to go into place without reeving, and these gaps are made watertight with small cast steel collars, all to one pattern, riveted to the rim and inner flange of the channel frame. The body of

the bulkhead is formed of channel steel, 30 inches by 3½ inches by 3½ inches, or of flanged plates of the same width between the flanges, fitted horizontally, attached at the sides to the rim plate, and terminating near the middle line against a semicircular tube of the same thickness as the bulkhead plates. This tube extends from the tank top to the upper deck, and is intended to act as a buttress giving support to the bulkhead amidships. It also serves to give access to the well, and forms the downcast shaft for ventilating the hold, as will be explained later on.

Between each pair of flanged plates, at the sides, in way of the longitudinals, a strong horizontal plate bracket, extending about 30 inches before and abaft the bulkhead, is fitted and riveted to each longitudinal. From the inner edge of this bracket plate to the tube at the centre a stiffening angle is fitted between the flanges. By this arrangement the stress on the bulkhead frame is transferred to the longitudinals, and the loss of section due to the closer pitched holes in the bulkhead frame is more than restored. The greater part of the riveting in the bulkheads can be done by hydraulic riveters by means of the apparatus, already referred to, designed for riveting the longitudinal framing.

Ventilation.

Owing to the greater depth of the side girders and beams, a method of ventilating the holds is practicable, which it is believed would effectually prevent sweating (see Plate XIX.). The downcast shaft at each bulkhead is fitted with a cross-pipe at the bottom. Through this pipe a current of air is conveyed to each side between the frames, outlets are provided on deck at the opposite end of the hold, and as both frames, longitudinals, and beams are perforated with holes along the line of their neutral axes, a

Several other minor variations affecting the hatches and hatch beams, shell plate butts and butt straps, shell doubling plates, hold pillars, etc., intended to secure greater economy in construction, need no detailed notice, as the foregoing description sufficiently indicates the principal features of the constructive scheme.

For many years the practical details of ship structure have remained in a state of "arrested development." We are passing through a period of great depression, when cheaper production becomes doubly important. Whatever may be thought of the suggestions now submitted to the judgment of experts it is hoped their consideration may do good, and peradventure open up a road to further economic progress hitherto unexplored.

NOTE.—Should there be difficulty in procuring the large sections of material introduced, the several modifications, keel excepted, may be carried out with the usual sections, supplemented by flanged plates for the longitudinal intermediates. The extra cost where modern flanging machinery is available would be trifling compared to the saving in riveting, and greater correctness of workmanship ensured by this system of construction.

DISCUSSION.

Mr. T. MILLAR said, in opening the discussion, that he thought Mr. Bell a bold man to bring his proposed scheme before the members of the Institution in its present form. Many substantial advantages were claimed for the proposed new system of construction, but in his opinion Mr. Bell failed to prove satisfactorily wherein these advantages lay. Two midship sections were given, evidently for purposes of comparison, one of a vessel built to Lloyd's, the other of a similar vessel arranged on the proposed system. This at once raised an important question—viz., had Mr. Bell's proposed system been submitted to and approved by Lloyd's committee?

The PRESIDENT—I should think not, Mr. Millar.

Mr. MILLAR—Then it seemed premature to assume the proposed section equal to that of a vessel which had been built, and no doubt when the members of the Institution had expressed their views on the subject Mr. Bell would see that Lloyd's might object seriously to several of his proposals in their present form. Mr. Bell might be under the

impression that most of his proposals were new, but such was not the case, as several of them have been carried out in vessels which are now in active service. *Keel.*—Although the ordinary slab keel is at best a compromise, it cannot be said that the proposed keel is any improvement upon it, either for strength or efficiency. *Framing.*—Mr. Bell claimed that by his method of framing the register tonnage was reduced without loss of stowage capacity. That he failed to see, and on measuring the two sections in the ordinary way, *i.e.*, inside of sparring and half depth of beams, he found there was two per cent. more area in the vessel with ordinary framing. If the capacity for cargo were measured to inside of shell plating, Mr. Bell's contention would hold good, but as it would be necessary to fit sparring on the inside of the frames, it was obvious the increased depth of frames would reduce the cargo space as well as the tonnage. As it did not seem possible to carry out the method of framing proposed, at the ends of the vessel, at anything like a reasonable cost, it would be necessary to resort to ordinary framing, in which case much of the advantage claimed would be lost. *Framing.*—In enumerating the construction advantages it was stated that a large part of the framing now having to be furnaced would be dispensed with, but the fact that the framing proposed would be more difficult to furnace seemed to be ignored, besides, if the system were carried throughout the vessel some of the longitudinals would require to be furnaced. Should the method proposed be carried all fore and aft, it was suggested that the frames be twisted to stand square to the curvature of the ship's side, an arrangement which might suit everything except the beam connections. *Floors.*—The structure of floor suggested was carried out in a somewhat similar but more efficient fashion in a steamer built in Walker shipyard in 1888. As regarded the

thinner, as there were no rivet heads in the vertical flanges of the frames to cover, and the limber holes could be kept close to the root of the frames. The writer proposed that the top and bottom members of the floors outside the double bottom be formed by splitting the channel frames. As the intermediate frames extend to the first longitudinal only, and they appear to be split to within 6 inches of same, it would be quite as good a job, and certainly much cheaper to use plain angles for this purpose. With the long frame it was quite a different matter, it being the ordinary practice to split channel or Z bars when either section was adopted for frames. Great stress was laid upon the longitudinal being in duplicate, so that no mistake need arise when they were being put in position. This statement was somewhat misleading, as the longitudinals were formed both of T bars and angle bars, and it was proposed to introduce T bars across the vertical butts of the shell plating to increase the rivet attachment. The proposal was all right if one could depend upon having the different sections fitted in their respective places, but there would always be a delightful uncertainty with regard to the pieces over the shell butts being in their correct position when the plates came to be templated. The riveting of the longitudinal to the main frames was totally inadequate, even if the longitudinals had not been called upon to perform any work, but angle lugs having three rivets through the frames and two rivets through the longitudinals could hardly be looked upon as an efficient connection for 12 inch bars. *Beams.*—The deck beams were the same section and spacing as the main frames, the deck plating being increased $\frac{1}{20}$th to compensate, one would suppose, for the wide spacing. If necessary to increase the thickness of the deck plating, why reduce the stringers by $\frac{1}{20}$th in thickness? The beam knees were dispensed with as being "at best of doubtful structural use;" but directly afterwards it was proposed "to fit one or more strong partial bulkheads in each hold to assist the bulkheads, and compensate for the absence of beam knees," which sounded contradictory, to say the least of it. *Plating.*—It was stated that "the area of unstiffened plating was nowhere greater than at present;" but if the two sections were compared it would be found that the area of unstiffened plating on the proposed section was in many places much in excess of the ordinary arrangement. It was not clear how the conclusion had been arrived at that the system of framing proposed offered special facilities as regarded fitting long plates, or that they could be templated and punched in much less time than now required. It was quite possible to fit plates as long and as broad on the one system as on the other, without structural detri-

ment; and surely it was easier to make an overlap than a flush seam if it had to be a close fit. That the plates could be templated or punched any quicker was doubtful, and it was assumed as correct that "the area of unstiffened plating was nowhere greater than at present" it was reasonable to assume that the number of rivets connecting the plating to the frames, etc., would be approximately the same in either case, although it was stated that the number of seams would be reduced, and about half the present number of holes saved. Some of the assumed saving in rivets would disappear when seam strips were fitted large enough to keep the plating joints together, as the single riveted strips proposed would hardly be sufficient for this purpose, even with the assistance of the T bar longitudinals and rivets in double sheer. *Stringers.*—The adoption of large shell bars or flanged plates for connecting the stringers to the shell was not by any means new, as it had been introduced into various steamers built at Walker shipyard since 1891. *Bulkheads.*—The system of bulkheads proposed did not appear to be of a simple nature, several important features having evidently been disregarded. Nothing was said about the butts or vertical stiffening, but perhaps it was intended to do without either, in which case it was evident the question would require further consideration. The arrangement proposed had several drawbacks, viz., the number of collars entailed by the longitudinals, the amount of caulking involved in the arrangement of the stiffeners, and the liability to damage from cargo, owing to stiffeners being placed between the flanges of the plates. The number of knees fitted, to compensate for the bulkhead frame being single, was also objectionable. *Riveting.*—The connections shown on the various plans were in most cases out of all proportion to the sections of material proposed, and would require to be

extra cost of material would not more than counterbalance any estimated saving there might be in labour. While there were makers enterprising enough to make rolls for almost any section of material, provided they were sure of paying orders, it was extremely doubtful if any maker would care to tackle 30 inch channel bars for shipwork. Failing the proposed sections, the writer said we could "fall back on the usual sections, supplemented by flanged plates," which seemed to effectually dispose of any advantage which might be claimed for the proposed system. Mr. Bell, he thought, contradicted himself in many parts of his paper, and failed to prove his case, as he assumed the scantlings and connections proposed were sufficient, and arrived at certain conclusions which seemed erroneous. Most people were glad to welcome any new ideas which would tend to lessen the cost of production, but were not at all willing to accept them unless backed up by something more than mere assertions, and he for one should have been glad had Mr. Bell placed before them in a more definite manner where and how his proposals would prove cheaper and better than the present method of ship construction.

Mr. R. H. Muir said he could not agree with Mr. Bell that "For many years the practical details of ship structure have remained in a state of arrested development." To his mind the progressive development, especially of the last ten years, had been such as to make builders proud of their achievements. If this progress had not been so rapid as Mr. Bell would wish, might it not be due to conditions imposed on the builder? Owners generally drew out their own specifications to suit their special trade, and with a view to insurance and class, possibly they were a little conservative in their notions of structure. Again, part of the reason for what Mr. Bell calls "arrested development" may be due to the very thing he advocated in his paper, viz., the dealing with sections of material not commonly used in the shipyard, and for which the present tools would be of little use. Builders were not prepared to discard their old tools all at once and replace them with new, however much it would please tool makers; and steel makers were in the same position. For instance, very few builders had angle shears to cut 12 inch angles forming the bottom frame, and still fewer had shears to cut 12 inch channels. He did not say that was any objection to the system, for given the tools many things might be improved. He could not agree with Mr. Bell on the use of the word "new" in the title of this paper, as the general ideas (details excepted) had already been adopted in many large vessels. As to details, take the upper deck stringer, the arrangement given in the paper was an angle bar

attached to the shell, and the stringer plate riveted on its inner edge, whether this method was good or bad he would leave Mr. Bell to say. On page 221, under *floors*, paragraph 2, talking of the ordinary solid plate floor attachment to the frame bar, it is stated :—"In the writer's experience where damage to the bottom of cellular vessels has been sustained the light bottom angle connecting the floor plate to the skin is the first to give way. The rivets sheer and the bar is forced up, thus destroying the efficiency of the girder before the power in resisting distortion, due to its depth, has been exerted." That statement hardly agreed with his further statement (page 225) for a similar arrangement :—"In this way waste of material is avoided and labour saved, while the value of the attachment between the stringer plate and the shell is in no way impaired." Which could they accept? Why not carry the stringer plate out to the shell and attach to the sheer strake in the ordinary way? There was no cutting out for the frames, as the frames above were from deck to deck, and held at the bottom with a lug angle. It might be worth considering the cutting of the frame at the main deck as well for many reasons. *Beams* (page 225, eighth line).—Describing the beam end attachment, Mr. Bell said : "This attachment is thought sufficient without adding knees, which break up stowage, and are at best of doubtful structural use in vessels having numerous transverse bulkheads." That was a delightfully open expression, and quite refreshing in these days of "arrested development." But take the last sentence : "To assist the bulkheads and to compensate for the absence of beam knees"—why compensate for a thing that is "of doubtful structural use ?"—"it is proposed to fit one or more strong partial bulkheads in each hold between the present transverse bulkheads." Describing No. 1 section, he claimed by increasing the

the two sides of the vessel apart and in true form; secondly, the subdividing of the interior into such compartments as will enable her to keep afloat should one or even two of such compartments get bilged. This latter (in a modern vessel) was the more important, and implied that the bulkheads should resist the water pressure. A little consideration of the Bulkhead Commission's Report would have shown Mr. Bell that vertical stiffening was necessary, and theoretically ought to increase with the depth. There were some other points he should like to have touched upon, *e.g.*, the system as a whole was 3-ply riveting, in some cases 4-ply; this should be avoided. He thought if Mr. Bell had had the President's experience of riveters' lists he would somewhat modify his proposed section.

Mr. E. W. De Rusett remarked that he thought there would be an objection to the author's very radical system of construction by the very free use made of bulb angles, for so far as his experience went bulb angles were difficult to work. He did not say that with regard to frames, but with reference to keelsons, as they were so difficult to get close. There were also an unusual number of pockets for dirt formed by the stringers. In practice these were very objectionable, costing so much to clean out that an inspector to a vessel building in a Tyne yard specified for those, in an ordinarily constructed ship, to be filled up with cement. With regard to the proposed extensive use of channel sections he had recently submitted a section with channel beams, but Lloyd's would not accept them without such an increase in section as to render their adoption prohibitive; the reason given being, that experiments showed this section for beams to be relatively weak. One member had said it would be difficult to get 15 inch channels rolled, but his firm had used them for bulkhead stiffeners in a "tanker," where they answered their purpose satisfactorily; and they had no difficulty in getting them of that size. With regard to the shell plating, he considered the edge to edge system very strong, but it would, he thought, be very costly, and difficult to work in conjunction with the stringers. Firstly, because the flange of the T bars being only 7 inches, did not, he considered, allow sufficient scope to get the plate edges fair, and to make a proper job of the riveting; and, secondly, because he thought it would be very difficult to get the sheer of stringers and plating to run together, especially at the bilge, where the lowest stringer soon rising from the tank side would necessitate the introduction of another strake of plating. Besides, the seams being only single riveted, Lloyd's, in fairness to builders adopting the present rule system of plating, could not pass them.

The PRESIDENT said if Mr. Bell had had any experience in submitting sections he would have felt that the number and size of these "lighteners" would have to be considerably modified. As to the pockets, the 4-ply riveting, and the joining of the shell plates edge to edge, to be of any use they must fit close. With respect to the saving in riveting, one important point Mr. Bell had forgotten in his political economy was that of the labour question, because as they reduced the quantity of riveting it was invariably found that the men demanded an increase of price. Consequently, much of the expected saving would be discounted. In the bilge any attachment whatever of the tank flange and fore and aft girder was simply dependent upon the shell plate, because the bracket knee appeared to be only a gusset plate. As to the question of capacity, for loose cargoes, such as grain carried out to the skin, the proposed system might give a better capacity, but this would not be so in the case of deals, because the net register was nearly the actual capacity for timber.

The discussion was adjourned, and the meeting concluded.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893–94.

PROCEEDINGS.

SIXTH GENERAL MEETING OF THE SESSION, HELD IN THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, MARCH 17TH, 1894.

ROBERT THOMPSON, ESQ., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on February 13th, 1894, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, Messrs. H. Withy and G. W. Sivewright were appointed by the President to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Ampuero, Senor, Engineer, Chief of the Chilian Cruiser "Presidenta Pinto," Circulo Naval, Valparaiso.

Archbold, William, Engineer Draughtsman, c/o Messrs. E. Scott, Mountain, & Co., The Close, Newcastle-on-Tyne.

Campbell, Thomas, Shipbuilder, 2, St. John's Terrace, Jarrow-on-Tyne.

Dickie, James, Shipyard Superintendent, Union Ironworks, San Francisco, California, U.S.A.

Dugdale, William H., Shipbuilder, Green Bank, Jarrow-on-Tyne.

Nevins, William, Inspecting Engineer, 28, Brookbank Road, Lewisham, London, S.E.

MEMBERS (LATE GRADUATES).

Davis, Thos. Wilfrid, Marine Engineer, Birkenfeld, Bromley, Kent.

Swan, Chas. Sheriton, Shipbuilder, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne.

ASSOCIATE.

Walker, James, Merchant and Shipbroker, c/o Messrs. Gilchrist, Walker, & Co., Constantinople.

GRADUATES.

Pendred, L. St. L., Draughtsman, 100, Westmorland Road, Newcastle-on-Tyne.

Rappoport, Fred. G., Apprentice Engineer, 6, North View, Heaton, Newcastle-on Tyne.

Stephenson, Robert, Apprentice Engineer, c/o Messrs. Robert Stephenson & Co., Limited, Newcastle-on-Tyne.

Swan, George, Apprentice Engineer, Grove House, Gosforth, Newcastle-on-Tyne.

Thornley, Thomas W., Apprentice Engineer, 58, St. Luke's Terrace, Pallion, Sunderland.

Walker, Gavin Knox, Apprentice Engineer, c/o Messrs. E. Scott, Mountain, & Co., The Close, Newcastle-on-Tyne.

Warburton, John A., Engineer Draughtsman, 15, Nelson Street, Sunderland.

Wilson, John R. S., Apprentice Engineer, Roseworth Tower, Gosforth, Newcastle-on-Tyne.

Mr. Frank Caws replied to the discussion on his paper "On Certain Principles of Motion, as taught by the Pendulum," etc.

The discussion on Mr. William Bell's paper "On a New System of Construction for Large Vessels of Cellular Type" was resumed.

MR. FRANK CAWS'S REPLY TO THE DISCUSSION ON HIS PAPER "ON CERTAIN PRINCIPLES OF MOTION, AS TAUGHT BY THE PENDULUM," ETC.

Mr. FRANK CAWS, replying to the discussion on his paper, said Mr. King, in the singularly able maiden speech with which he opened the discussion on this maiden paper, erected a strong outwork in defence of the pendulum speed-power meter theory, thereby entitling himself to the thanks of the author of that theory and inventor of that instrument. The gauge of the ship's speed, though very nearly, was not exactly the theoretic vertex speed, as Mr. King seemed to think, but related to it thus :—

$$\frac{\text{ship's vertex speed}}{\text{theoretic speed of restrained pendulum}} = \frac{\text{A O Y}}{\text{A O Z}}.$$

One expression of Mr. King's in reference to the displacement-replacement operation seemed to imply that this operation was characteristic of the model in meter rather than of the ship under weigh at sea. But the operation was in both cases simply this, the ship continually plunges like the model, with all the energy of her mass momentum into the undisturbed water ahead, the acceleration of whose fluid mass bears to the momentum of the ship's own mass the same relation as to the model's own mass. The hydrodynamic equivalence between the two cases was absolute. Mr. King laid too much stress on the question of corresponding smoothness of model and ship. It was quite true, as Mr. Macoll intimated, that the difference of resistance due to one model being less highly polished than another was practically inappreciable. In several cases models after being tested at a variety of speeds, had been scraped and repainted with a different kind of paint, and tested again at the same speeds, with substantially the same results as before. But though Mr. Macoll used the expression "rough models" he, of course, spoke within certain implied limits, such as would not extend to a surface foul and barnacled. The author once tested a smooth board's resistance, and then tested it covered with bristles standing out like a brush. In the latter case the increase of resistance was of course enormous. It was a common but very erroneous idea that skin resistance was wholly due to roughness. But those who thought thus overlooked this truth, that if the skin were almost absolutely smooth the

water would still cling to it simply by the great force of attraction, and an amount of skin resistance would still be developed nearly as large as it would be if the skin were of ordinary smoothness. On this account the want of absolute correspondence between the smoothness of model and of full sized ship was seen to possess much less importance than Mr. King attached to it; for from this view of the case they should be justified in regarding it as having no appreciable effect on the ratio of resistance of ship to that of model. In reference to Mr. King's thoughtful reflections as to analysing the components of ship resistance, they ought not to forget that the escapement wave was the resultant outcome not of some only, but of all these components. Thus skin resistance, as well as body resistance, helped to produce the escapement wave. The pendulum speed-power meter yielded the exact measure of energy consumed by the escapement wave at the given speed, and thus the experiment revealed the measure of total resistance due to the combined effect of the ship's lines and skin. Every one would agree with Mr. King that at low speeds $\frac{\text{skin resistance}}{\text{lines resistance}}$ was a larger fraction than at high speeds. But what that fraction really was at any speed no man knew. Questions of resistance whose answer depended on the value of this fraction could not be answered by calculation merely, that fraction being always unknown. Yet these were the questions which the pendulum speed-power meter answered at once with utmost accuracy, and in this service its utility was great.

That observation of the paper to the effect that dynamicians might differ about pendulums as geologists about chasms had found ample illustration in this discussion, as was to be expected. It was regrettable that Mr. Ferrier and Mr. Thomson both spoke apparently from a very cursory

with the real doctrine of the paper than from an unwitting misconstruing of its language and meaning. For example, on page 104, the paper said "the time taken by the pendulum bob in which to realise its vertex velocity exceeds the time in which the falling free mass descends from the A Z level to the O level, as the length of arc A O, or Z O, exceeds the length of the versine or vertical dip of that arc," which simply means that a body sliding unresistedly down a slope occupies more time than in falling plumb down the same height, the difference of time of sloping descent and of vertical descent being simply proportional to the difference between the length and height of slope. Of slopes absolutely straight this doctrine was absolutely true: and so nearly true of slopes such as those which were employed in working the pendulum meter (which, though not absolutely straight, had practically no difference of length from foot to summit, from what they would have if straight), that in working the pendulum meter up to a speed of (representing) 35 knots no error of the slightest importance would arise if the curvature were neglected. The curvature, however, was not neglected; and, moreover, the infinitesimal difference between the circular and cycloidal curvature had been carefully calculated and allowed for on the brass reading bar of the instrument, which was specially stated in the paper on page 120. Yet, strange to say, in spite of these statements in the paper, which were both explicit and correct, a not inconsiderable portion of Mr. Ferrier's speech was devoted to criticising them as though they had expressed the doctrine that the pendulum's period varied as its arc of amplitude! How Mr. Ferrier could have brought himself to attach such a gross misinterpretation as that to the plain language of the paper was conceivable upon no other hypothesis than that his opportunities had not permitted that careful perusal of the paper by which alone it could be understood. No schoolboy who had felt really interested in the story of Galileo watching the chandeliers swinging in the church, equal periods for all amplitudes, would be likely to commit so gross a blunder as Mr. Ferrier naïvely attributed to the author of this paper in this very respect. In the same passage of his speech Mr. Ferrier proceeded to particularise the difference between cycloidal and circular pendulum's periods, ignoring the statement on page 120 altogether. And in this earlier portion of his criticism Mr. Ferrier, referring to the statement of the paper that the pendulum's force was proportional to the sine of the angle of amplitude, and, admitting that to be so, added the intimation that the direction of the force was not horizontal but tangential to the circle, as if to imply that the paper had represented the force as acting horizontally. The truth was, the tangen-

tial direction of the force appeared in the mind of the writer so self-evident as to go without saying; and, accordingly, like many other geometrical and mathematical facts more or less intimately related but not appearing necessary to the particular argument, this detail was not specified.

Passing now from these superfluous, not to say hypercritical, to the more properly argumentative observations of Mr. Ferrier, they were met at once by his protest, in which Mr. Thomson united, against the application by the paper of the terms potential and kinetic to force and speed. Mr. Thomson said he could attach a definite meaning to the terms kinetic and potential energy, but he could not understand potential or kinetic force or potential and kinetic velocity. Now what was energy but a pile of accumulated forces? And what was force but the increment of energy? And what was resistance but the decrement of energy? Force, energy, speed, were co-principles of motion, absolutely inseparable, a veritable three in one, holding their potential and kinetic attributes in common. Conservation of energy involved of necessity conservation of force and speed. The reciprocal principle essential to conservation was expressed in the formula, Potential value + Kinetic value = Constant value; or $P + K = C$; as set forth in the paper. Deny that principle to force and speed and they denied it to energy also. Deny that principle to force and speed, and they denied it to conservation. They rendered that fundamental law of conservation void and of none effect, and thereby they exchanged cosmos for chaos. To prove that nothing but confusion could result from such denial, they need only seek to apply the words of Mr. Ferrier to the facts and acts of the pendulum. Mr. Ferrier contended (1) that "speed must be actual or non-existent at a particular instant;" (2) that "the speed at the beginning of the motion was nothing."

force = g, *i.e.*, greatest force obtainable by gravity! Here, again, at or near vertex, speed was at its greatest; and force was nothing! They were forbidden to regard the speed and force in any potential relation. Mr. Ferrier instructed them to value them according to their actual particular instant value. They had done so; and with this result that a zero speed was possessed of the greatest force; and a zero force was the due of the top speed! For the sake of a doctrine which thus led them into confusion worse confounded, they were invited by Mr. Ferrier and Mr. Thomson to pronounce erroneous that method of interpretation, which might be called the $P + K = C$ method, set forth in the paper, and which was the only rational interpretation.

Evidently Mr. Thomson had missed the true meaning of the paper; for he charged the paper with assuming the wave as existing "when the model was at rest." The misapprehension under which Mr. Thomson laboured here was evidenced by his use of the words "when the model was at rest." The paper assumed the presence of the wave not before the start but when the start was made. Before the start the model was truly at rest, and there was no unbalanced force to cause a wave. But immediately the severance of the leash was effected the unbalanced potential force was undoubtedly present confronted by its potential wave. The space of time engaged in severing the leash was quite infinitesimal. But it separated the state of rest from the state of motion. The invisibility of the potential wave seemed to argue with Mr. Thomson against its existence. Now if a hundredweight were suspended over a man's head, and he, looking up, saw the suspending cord suddenly cut, he would instinctively jump aside and save his life. But suppose he had reasoned that the hundredweight for the first one hundredth second after the cord was cut exhibited no motion and was in fact in a state of rest, because its motion was invisible. Then that man would probably lose his life from being slow to recognise the vital dynamic difference between zero speed previous to the cord being cut, and what Mr. Ferrier and Mr. Thomson insisted on calling "zero speed" the first instant following the severance of the cord. Mr. Thomson had the choice of alternatives. He might accept the view of constancy expressed by C in the formula $P + K = C$; or he might accept on the other hand a full power with no speed, and a full speed with no power! If he elected the former, then he necessarily chose with it that potential wave which properly belonged to it. To set against Mr. Thomson's opinion or *ipse dixit* that the whole stream-line action against the ship at uniform speed was totally different from what it was against the model in the pendulum meter, there was the fact that the wave contour of the model's

water-line at the moment of vertex speed is found to be an exact scale copy of the real ship's wave contour line when running at the corresponding speed uniformly. And a further study of this part of the subject can hardly fail to convince the sceptical that from the nature of things this result in similarity of wave-line action was not only possible but quite inevitable.

It was natural for Mr. Ferrier to take the circumferential rather than the dynamic measure of the mean speed of a cycloidal pendulum. And, having discovered that the mean circumferential speed was to the vertex speed as 1 to 1·57, it was natural, though a little rash, to conclude that the paper, which gave the mean speed as half the vertex speed, held a mistake in this particular. It transpired, however, that in this respect also the paper was strictly correct, the mean dynamic value of the speed of a cycloidal pendulum being always as the tangent of the initial angle of amplitude. For the cycloid being the arc of quickest descent whose tangents were equal to their corresponding chords of quickest descent of the rolling circle, the tangents were at once the measures of both the force and of the true dynamic space of any angle of amplitude; and the initial angle was the integral of all the angles comprised within any arc of amplitude. And just as the initial tangent was always = half its arc of semi-amplitude, so the mean speed represented by the initial tangent was always = half the vertex speed represented by the arc. (See Plate XX.) The remaining point in the paper which Mr. Ferrier pronounced incorrect and based on a fallacy was illustrated by Figs. 1, 2, 3, 4, and 5, Plate XX., which would speak for themselves.

On generally reviewing the statements of Mr. Ferrier on this occasion study and reflection could lead to no other conviction than that he had, unfortunately, been led upon too hasty and partial an examination to

the mean speed of that same pulse, which was enough for their purpose, and was indeed exactly what they wanted ; for it was even so that the mean, and not the maximum, ordinate of the diagram from the indicator was taken as the true power of the revolution or stroke.

That the principles taught in this paper were in profound harmony with the Newtonian system would eventually be manifest to all readers of it. Whatever differences of view might obtain for awhile as to the proper theory of the pendulum meter, all who had expressed themselves seemed to unite for the time being in the view of the President that the curves yielded by this instrument would prove valuable as an absolute, and much needed, basis of relative resistances of models.

It was unnecessary to refer at length in this reply to the encouraging and very kind observations of Mr. De Rusett and Mr. Macoll, who were well acquainted with the practical work of the pendulum meter, having for years watched with earnest interest its slow development, and helped the work forward by every means in their power. It was undeniable, as Mr. De Rusett pointed out, that with all model experiments, whether by the pendulum meter or other tanks, the great difficulty lay in bridging over the gap between effective and indicated power. There was no one better able to succeed in overcoming this difficulty than the shipbuilder or naval architect himself. But in order that he might succeed each shipbuilder or naval architect should have not one nor two but a considerable number of E.H.P. curves obtained by tank experiments to compare as a basis with the I.H.P. curves of the same ships. From such a basis he would be guided to a correct conclusion.

An outline sketch of the meter is given on Plate XXI.

To all who had by their kind attention as hearers, or by their contributions to the discussion on this paper, assisted the writer to introduce this subject, he desired most sincerely to express his thanks.

The PRESIDENT was sure it would be their wish to accord a very hearty vote of thanks to Mr. Caws for the valuable paper he had read, and the equally valuable reply he had given to the discussion. He moved that a cordial vote of thanks be given to Mr. Caws.

The motion was cordially adopted.

ADJOURNED DISCUSSION ON MR. WM. BELL'S PAPER "ON A NEW SYSTEM OF CONSTRUCTION FOR LARGE VESSELS OF CELLULAR TYPE."

Mr. G. W. SIVEWRIGHT, in resuming the discussion on Mr. Wm. Bell's paper, said he had not had the pleasure of hearing the paper read, but he thought it was one of an interesting nature, and was sure it would create an exhaustive discussion. One of the principal objects in shipbuilding was to so design the method of construction that a large number of men could be put on to each job as quickly as possibly. Having had considerable experience in mechanical shipbuilding of one kind or other, he quite understood the difficulties of Mr. Bell's position to get out a paper that would be above criticism, or, in other words, a design perfect to commence with. He had made a very careful examination of the paper, and he thought, with the ordinary methods and machinery now in use in shipyards, it would not be possible to construct the design of ship advocated as quickly as the style now generally adopted. Many shipbuilders have felt that in the past they have been building somewhat old-fashioned designed ships, and have endeavoured to invent improvements not only in the type of ship but also in the methods of construction; but in attempting this it ought to be considered that there was one important factor to be kept in view, and that was the economic principle of design. If they invented a design that would cost more to build than what they had hitherto been doing, there was always the fear that shipowners would not look with favour on the new method. There was one great difficulty in connection with new ideas in shipbuilding, and that was to get the register societies to take a design different from what they had been accustomed to, and this was more in evidence when the permission of a powerful register society like Lloyd's had to be obtained. For instance, he noticed in the paper on page 221, that with the design of bottom as proposed there would be a saving of something like 20 per cent. in material; he was certain of this, that a proposition of that kind would meet with a considerable amount of opposition irrespective of suitability of design. He was of opinion there were some difficulties in connection with the framing of the vessel which would run up the cost of this system of framing above the style now adopted. For instance, it was the practice, more especially where bulb

angle framing was used, to turn the frame, and the frame turners to take it straight down and lay it over the keel, but with a large frame, 12 inches in width, as proposed in the paper, he was afraid that after the frame was turned, to true the frame up again cold would be a difficult matter with ordinary methods; besides, they had a costly operation in splitting the frame at the bottom in the way of the tank side, which would necessitate smithwork; and also at the top of the frame it was proposed to put the frame through another operation by punching a portion off the inside of the frame in 'tween decks. These operations in connection with the framing would mean a large number of helpers, and would take a considerable time to do the work. The design of floor plate, he thought, was not an improvement upon what they were now using. It would be remembered in the old system of cellular bottoms that small plates in the shape of brackets were used: this system was not found satisfactory, as there was a difficulty to get exact workmanship, and the floor being in so many pieces delayed the work considerably. One of the advantages claimed in the proposed design was that there was less riveting, but he (Mr. Sivewright) had used a system of floor plates for a number of years that had no riveting at all, except where the floors were connected to the centre keelson, intercostal keelson, and tank side; and the majority of the floors were all made from one template. There was one portion of the design he considered would be open to very grave objection, and that was the 3-ply seam riveting in connection with the shell and intercostal keelsons; this would be a costly job, and would require very careful workmanship, and it appeared to him there would be an extra amount of drilling where each seam came across the frame; besides, where the holes came through the 3-ply it would lead to more riming of holes to make

the cost as regards labour. There was one part of the paper where it stated there would be a reduction of tonnage without a reduction of stowage. He considered a statement of this kind wanted some further explanation; for instance, they were not told where the cargo battens were placed in a framing of this kind; he supposed they would be put on the inside of the large frames, and if so this would of course reduce the tonnage without affecting the bulk grain capacity; but in a large ship of this description he was of opinion that in the trade she would go into, bulk grain would form a very small portion of her cargoes, and the proposed method instead of being an improvement, giving small tonnage with large cargo capacity, would act in the opposite direction, as the majority of Indian and American cargoes would be carried inside the cargo battens and main framing; and this difficulty to stow bulky cargoes would be further increased by the partial bulkheads proposed to be fitted at intervals in the holds. There were other portions of the paper he would like to comment upon, but he noticed that several other speakers had touched on the matter, but before concluding his remarks he would like to state that no matter what design is got out in connection with mechanical shipbuilding, the great difficulties to face are the two ends of the ship; if you alter the design at the ends you immediately set up a fresh number of difficulties and increase the complications of getting in material and having to set on different squads of men to those accustomed to the other mechanical portions of the work. This was a grave consideration in all mechanical shipbuilding, and he was much afraid there would have to be many special arrangements of plant to get over this effectually. He had come to the conclusion that successful mechanical shipbuilding greatly depended upon the amount of capital they were prepared to spend upon machinery plant. He hoped the discussion that had taken place on the paper would in no way discourage Mr. Bell, as any simple form of mechanical shipbuilding that would dispense with riveting would be a great advantage to all parties concerned. Many other shipbuilders have been working in this direction, and he (Mr. Sivewright) had done as much as he could to introduce a system of sectional framing in connection with cold flanging, large plates, etc.

Mr. A. McGlashan observed that the last paragraph, page 227, read:—"Whatever may be thought of the suggestions now submitted to the judgment of experts it is hoped their consideration may do good, and peradventure open up a road to further economic progress hitherto unexplored." He gathered from that that the writer, in putting forward

the paper, did not so much hope that shipbuilders would adopt the methods of construction proposed in it, as that the Institution would be stimulated by discussion to further investigation of the subject. There was, no doubt, a good deal of unrest in both the practical and designing departments of shipbuilding establishments. It was well enough known that the old methods did not give complete satisfaction, and since steel had become generally used there were greater possibilities than there were when they had simply iron to deal with. They had much larger plates and bars of various sections at command now, and a material that could be flanged and worked more severely than iron could. He thought, therefore, that the paper was opportune, though, of course, it would be necessary to disagree with a good deal that was in it if one were to criticise it exhaustively. As an illustration of a point on which they might disagree, take the new form of keel introduced, as shown on the midship section, and which consisted of the usual vertical plate passing down between the two bulb angles, 8 inches by 8 inches by 1⅛ inches. First of all, this had the usual amount of riveting in the vertical flanges, just as with the ordinary flanged garboard plates, then immediately alongside they had on each side an additional double row of rivets. In his conclusions relating to the keel the writer said:—"This modification will increase the lateral strength of the keel, remove all difficulty in securing good workmanship, now considerable, and cost much less than the present combination of 'slabs' and flanged plates." He (Mr. McGlashan) could not understand how increasing the riveting and jointing all along was going to reduce the cost or improve the work. Again, it might be questioned whether the introduction of so many bars of large section, angles, bulb angles, channels, etc., could be done at present with any

thing more than single riveting of the plate edges would be required to succour the riveting at the butts. Then they were told "a large part of the framing now requiring to be furnaced would be dispensed with;" but, looking round the midship section, one would fail to discover that this would be so; on the contrary, the furnaced work would be more difficult to deal with because of the larger section to be handled. There was no doubt that many ships had a straight body for about half their length, and it was possible, as was proposed, with reversible templates to prepare, before the framework was erected, a large number of parts ready for fixing in position. It was therefore desirable that there should be a multiplication of equal parts, which could be produced beforehand, and in this way a large number of men could be got to work, and more rapid progress made with building. While, however, ships were usually parallel in breadth, yet the sheer affected the height considerably within the half-length, and these templates would not be so easily applied towards the ends of the half-length. Still, he thought there was a great deal of possibility in the suggestion to do a large part of the work from interchangeable templates. A section showing a bulkhead was given in the paper, but he (Mr. McGlashan) thought it was too complicated to supersede the present method. With the arrangement shown on the accompanying drawing, he thought, if the brackets were sufficiently strengthened, the passing of the bulb angles through the bulkheads might be dispensed with altogether. It was done to some extent at present. Indeed, many of the large vessels built on the web-frame system had no keelsons passing through the bulkhead between the tank side and the deck stringers. While they were attempting to deal with ships as they would with lattice bridges, they must ask what would be the effect on a lattice bridge if it were fully loaded and inclined to an angle of 45 degs.? As ships are required to carry their loads equally in many varying and trying positions he thought there must be something more than mere strut work, even in their cellular bottoms. Notwithstanding these criticisms, he had derived pleasure from reading the paper, which was valuable in many ways and worth being discussed.

Mr. D. Andrew said he laboured under the disadvantage of not being a shipbuilder, and therefore could not discuss the question of construction; but there was one portion of the paper in which he was interested, viz., ventilation. By the means Mr. Bell described, he claimed he could ventilate the holds. He (Mr. Andrew) was at a loss to understand how his system of ventilation would accomplish that object.

As he understood it, he took his ventilation down a shaft on the bulkhead at the centre of the vessel and through smaller shafts laid on the ceiling to each side, and passed through the new system of framing. No doubt this would give very good ventilation to the shell of the vessel, but he (Mr. Andrew) failed to find wherein that it would ventilate holds or cargoes, such as grain, jute, or rice. He would like if Mr. Bell would give some further explanation in regard to how, by these means, he could ventilate cargoes. He mentions it as a safe system of ventilation in bad weather, for on page 226 he says:—"As the downcast shaft at the bulkhead is in open communication with the tank well, the ventilation of the holds may be maintained in bad weather without danger to the ship or risk of damaging cargo through a sea finding its way down the ventilator." He (Mr. Andrew) concluded from Plate XIX. that this pipe of Mr. Bell's was carried across on the top or ceiling of the tank and led into the well at the sides; but should that large ventilator ship a heavy sea an enormous quantity of water would get down, which would require a very large well to carry it off, and the result would be an overflow and damage to cargo. What they wanted was a safe ventilator in bad weather, one that would exclude the water, one that would act automatically, and only admit the air in the event of a heavy sea breaking on board. The outlet or vent would also be a source of danger. Perhaps Mr. Bell would give them some further information on that point.

Mr. H. Withy said in looking at the midship section (Plate XVII.) it occurred to him that, with 10 inch bars and other odd sections, the great bulk of the material would cost something like £2 per ton extra, and he did not think that the method of construction proposed was anything at all equal to the ordinary floors flanged on the top and bottom

obtaining very little sympathy. A paper like the one under consideration might be viewed from several aspects or standpoints. The principal or primary objection taken to the proposed plan was, owing to its comparative saving in material, it would not be accepted or passed by the registry. Well, that was an objection good enough so far as it went, but not, in his opinion, sufficient to condemn any paper *in toto*. Generally speaking, it might be borne in mind that all registry or classification societies were not in their nature (under existing conditions) originators, inventors, or leaders. All alterations, innovations, and improvements, came from outside, and it was generally after a severe and prolonged struggle that anything new or out of the common was approved by the said registries or recorders. Even Lloyd's did not at first class iron vessels, later steel vessels, or still later bulk oil carriers, at their first introduction. It was a very difficult matter to design a system of longitudinal construction which would not in some points compare unfavourably with the ordinary transverse system above the double bottom. Longitudinal systems of iron shipbuilding were by no means a novelty, as, for instance, vessels built by Scott Russell forty years ago, and more or less by the Admiralty in the construction of the "Warrior," "Bellerophon," etc., some thirty years since to the present date. Were it permissible for ordinary cargo or passenger purposes of the size given in the paper, and the scantlings made in proportion to a Royal Navy vessel of similar size at the present day, a still further reduction in weight would be obtained than was made by the writer of the paper; and this reduction if applied to reduce the large size of some of the parts would materially increase the probability of its being tried. Unfortunately, in sea-going vessels it was impracticable to adopt any modification which was best all round, so many considerations came into play that it eventually became a question of compromise with everything in the whole structure. In Navy vessels the large pockets formed by webs and longitudinals were not so objectionable as on board merchant vessels, as internal capacity or stowage room was not of so much importance. Again, in any system of longitudinal construction the pockets would always be detrimental, not only from the space they took up, but also the difficulty of cleaning out thoroughly after the cargoes were discharged. In ordinary vessels large quantities of decayed grain, together with coal dust, oil cake, cotton, etc., were frequently seen in the frame and stringer spaces and elsewhere. Now, in a longitudinally constructed vessel these pockets or recesses, which became lodging-places for rubbish, would likely be more numerous and deeper in area than ordinarily, and so become more offensive than at present. Of course this

would be largely, if not entirely, obviated by having the vessel properly cleaned out after each cargo was delivered. The existing conditions, however, were not in favour of this being done, the tendency to despatch being gradually more accentuated. The writer of the paper places great stress and claims considerable advantage on the arrangement of shell seam attachment, whereby the seam rivets are in double sheer, and also on the much easier application of machine riveting to the shell rivets than by the usual out-and-in system of plating. It being necessary to have the machine deep enough in the gap to stride one strake only; also the shell packing was saved which ought to give sounder riveting to the frames, there being no outside strakes. This edge-to-edge system of shell plating had been adopted in some vessels in the Atlantic trade having all the shell plates on the frames, and the seam straps were increased in the middle part of the vessel in some cases at the bilge, and then the seam straps were extended in width until the shell was entirely doubled, and so made a strong and substantial piece of work. His own impression was, however, that it was not quite the cheapest method of fitting the shell plating. He agreed with the remarks that had been made about the difficulty there would be in fitting the shell seams on the 6 inch flange of the longitudinal. But it was a very easy matter to increase the width of this flange and also the outside seam strap to correspond, and this would also enable the seams to be made straight for the length of each respective plate, so that the edges would be dressed by the planer, and by having close and well-fitted seams the structure would be materially stronger and lessen the strain on the rivets. With regard to the proposed ventilation, his impression was the writer of the paper intended this arrangement quite as much for the purpose of venti-

being convinced of this had expended a considerable amount of time and labour in arranging the proposals he had put forth before them, and it went to show it was not quite so easy to introduce important alterations in the present system of shipbuilding as some were inclined to think. To obtain something new, simpler, more effective, and more economical than in use at present was very desirable, and he thought they should welcome all attempts in this direction; and the field was still open for intrepid investigators.

Mr. Geo. N. Arnison, Jun., said it was no doubt difficult to take part in the discussion without adding to the adverse criticism of the proposed new system of construction for large vessels of cellular type. There was, however, at least one feature in the new form of keel that was commendable, viz., that there were only three thicknesses requiring riveting as against five thicknesses in the keel shown on Plate XVI. It also appeared to him (Mr. Arnison) that Mr. Sivewright was probably somewhat too severe in his reference to stowage. In the paper it was not claimed that there was increased stowage, but that "the register tonnage is reduced without reduction of stowage capacity, and the cost of dunnage and stevedoring is lessened." If the midship sections in Plates XVI. and XVII. were compared it would be seen that in the former the three side stringers, by projecting inside the framing, considerably interfered with the stowage of bulky cargo, and he thought that even Mr. Sivewright would on further consideration admit that in this respect there was an advantage in Mr. Bell's proposed method of construction. The last speaker (Mr. Macoll), when referring to the external longitudinal straps, proposed to be fitted to connect the strakes of shell plating, very properly pointed out that single riveting appeared to be insufficient, and that in Atlantic steamers, when the shell plating had been fitted in a similar manner, there had been a complete doubling of the plating by means of the connecting outside strakes. This statement was correct so far as concerned the upper and main sheer strakes, the upper side and bilge plating, but elsewhere he (Mr. Arnison) knew that in the largest steamer with its shell plating so arranged that the outside strakes were of only sufficient width to take three rows of rivets on each side of the longitudinal edges of the inside strakes. Care was taken that the planed edges of the inside strakes should fit close at the longitudinal edges, so as to relieve the rivets from undue strain. Although in Mr. Bell's proposed arrangement of framing the transverse frames were spaced further apart, yet it could not be said to approach a longitudinal system of framing; for in the bottom

there was a great lack of longitudinal strength, as from the central keelson to the tank side plates there was no continuous attachment uniting the inner and outer bottoms, and all the longitudinal intercostal plates stopped at the vertical frames. He (Mr. Arnison) could not agree with a previous speaker (Mr. McGlashan) that the stringers and keelsons might stop at the bulkheads instead of being carried through them; such a suggestion was to revert to the practice of a quarter of a century ago. He had seen the evils of centre and bilge keelsons not being carried through engine and boiler room bulkheads, and knew something of the expense incurred in endeavouring to overcome the original defective construction. Reverting to Mr. Bell's paper, Mr. Arnison remarked that under the head of beams, that the author proposed "to assist the bulkheads and to compensate for the absence of beam knees, it is proposed to fit one or more strong partial bulkheads in each hold between the present transverse bulkheads." Seeing that the beam knees are proposed to be omitted because they "break up stowage," would not the remedy be worse than the disease, as partial bulkheads seriously interfere with stowage and only in a lesser degree than web frames, if wider spaced? In concluding, he (Mr. Arnison) concurred with those who had objected to 3-ply riveting, and agreed generally with the remarks of Mr. Sivewright and others as to the practical disadvantages of the proposed departure.

Mr. McGlashan wished to explain in regard to the remarks of the last speaker, who said he "could not agree with a previous speaker that the stringers and keelsons might stop at the bulkheads." He (Mr. McGlashan) might tell him of ships 360 to 380 feet in length which had no side stringers such as shown on this midship section carried through the bulkheads. In web-framed ships there were none of the longitudinal

otherwise. He would like to see a system of ventilation elaborated and carried out in a more workmanlike manner than it appeared to be, though he thought it a step in the right direction.

The PRESIDENT thought Mr. Bell had rather spoiled his own case by the insufficiency of the plans submitted. They had midship section plans only, without sheer plan and no detail of the bottom of the vessel, which left them practically with very little to work upon, so far as the ends of the ship were concerned. On the section there were seven of intercostals, and he (the President) would rather like to see how these finished at the ends of the ship. It appeared that Mr. Bell had a model, but it had not been sent to the meeting; had this been done it would have allowed them to understand the matter better. He thought, with Mr. McGlashan, that these were the sort of papers they wanted. If the papers were perfect they would not be worth discussing. Mr. Bell would probably have bettered his case had he left the subject of ventilation alone, and dealt only with the method of shipbuilding. The matter of ventilation could have been discussed afterwards, because the impression they got from this midship section was that it was all ventilation. If they took this section and sent it up to Lloyd's, the first question would be the area of the lightening holes through the bottom, which were shown to be about double what they were in the ordinary ship. The attachment of the ordinary keelson seemed to be practically *nil*, and the same applied to the tank flange plates. The frame there and the connection was, he thought, very weak. There was no doubt that some things were as old as Noah's ark, but the question was—was there anything new? They had so many new ideas started, and eventually found that they had been in existence before. He thought there were periodic changes which people adapted themselves to. It would seem as if they got tired of a style of building and they wanted something new; well, someone studying this paper might hit upon something newer and even more workable. He thought Mr. Bell deserved every credit for the way he had formulated his new plan; but if he had given them fuller drawings he would have helped his case more than by submitting to them only two or three sections, and confusing the matter with the question of ventilation.

The SECRETARY said Mr. Bell might be able to come to their next meeting to make his reply and bring his model with him.

The PRESIDENT—It would be much better for the *Transactions* if he could give them some more detailed plans.

OIL ENGINES.

By WILLIAM STAFFORD.

[Read before the Institution, in West Hartlepool, on Saturday, March 17th, 1894.]

The value of oil as a means of producing motive power has long been understood and appreciated, and many and various attempts have been made to employ it in an effective and economical manner. For this purpose a great amount of ingenuity has been expended in perfecting systems in which the oil was used as a fuel in lieu of coal, some of which are still in existence and are said to be doing very well.

Again, it has been used as a vapour to drive the piston instead of steam. Used in this way it is pumped from the supply tank into a heated coil called the generator. There it is heated and converted into vapour and turned on to the engine instead of steam; the exhaust is led into a condenser, where it is restored to a liquid form, thence it is pumped back to the supply tank, from there to the generator, where it is re-evaporated and used over and over again.

The oil engine under consideration, however, differs from both these systems in being an internal combustion engine, into the cylinder of which the oil (having first been converted into vapour) is introduced, mixed with a sufficient quantity of air, and there exploded, the impact of the explosion acting directly on the end of the piston, thus producing motion.

Engines of this class—that is, internal combustion engines—undoubtedly have a great advantage over other engines, in that the whole of the products of combustion, and the whole of the heat contained in the fuel, is generated and developed in the working cylinder itself, and in direct contact with the piston to be driven, instead of the heat contained in the fuel being merely transmitted through the plates of a furnace or combustion chamber, or through the thickness of a set of tubes.

Many systems for using oil as a motive power in this way have been tried and patented in years gone by. To go back into ancient history and describe these is no part of this paper, but rather to consider a few

of the best known engines of this class of to-day in such a way as to add to our collective knowledge of the subject, and, by initiating a discussion, to add at least some contribution to the many very valuable papers, read before this Institution, on almost every branch of engineering except the one before us.

Amongst the best known oil engines of to-day may be mentioned the "Priestman," the "Crossley Brothers," the "Hornsby-Akroyd," and the "Rocket."

The writer will give a brief description of each in the order in which they have been named, along with such reliable data as he has been able to obtain in connection with each.

To Messrs. Priestman Brothers, perhaps, belongs the credit of having first improved the oil engine to such a degree as to render it capable of working successfully with a heavy and safe oil.

The Priestman Oil Engine.

Generally speaking, the Priestman oil engine is similar in form to the oil engine shown in Plates XXII. and XXIII.; only instead of the stone foundation, a cast iron tank extends the full length of the engine, one part of which is used as a supply tank for the oil used, and the other part as a cistern, containing the water which is circulated round the cylinder jacket by a small pump for cooling purposes. In some of these engines the water is circulated by gravitation from a tank. A small hand pump is fitted in connection with the oil tank to put an initial air pressure on the oil, this pressure being maintained after the engine is started by an air pump on the engine, driven from an eccentric, as the oil and air necessary for combustion is put into the vaporizer under pressure.

into the cylinder, there it is compressed by the return stroke of the piston, is then fired by an electric spark, and, exploding, drives the piston on another out stroke, then is expelled through the exhaust valve as the piston returns, the cycle being the same as in the gas engine viz., the four cycle movement.

To start the engine the oil tank is put under pressure by the hand pump, and the lamp lit under the vaporizer; when this vaporizer is hot enough the cock is opened to admit oil and air to it, the fly-wheel is then turned a few times, a charge of explosive mixture enters the cylinder, and, being compressed by the backward stroke of the piston, is ignited by the electric spark, an explosion takes place and the engine starts. These engines have been very extensively applied. Professor Unwin, who made some experiments with one of these engines, gives the following as some of the results obtained by him :—

TRIAL I.

Mean effective brake load	73·64	lbs.
Mean speed...	207·73	revolutions per minute.
Mean effective pressure in cylinder ...	41·38	lbs. per square inch.
B.H.P.	6·765	
I.H.P.	7·408	
Engine friction	·643	H.P.
Mechanical efficiency	·91	
Oil used per hour	6·4	lbs.
" " B.H.P. per hour	·946	lbs.
" " I.H.P. per hour	·864	lbs.

TRIAL II.

Mean effective brake load	38·2	lbs.
Mean speed...	214·29	revolutions per minute.
Mean effective pressure in cylinder ...	25·48	lbs. per square inch.
B.H.P.	3·62	
I.H.P.	4·706	
Engine friction	1·086	H.P.
Mechanical efficiency	·769	
Oil used per hour	5	lbs.
" " B.H.P. per hour	1·381	lbs.
" " I.H.P. per hour	1·063	lbs.

The electric spark for ignition is obtained from a bichromate battery and induction coil.

THE CROSSLEY BROS. OIL ENGINE.

This engine is very similar to the Priestman, having its store of oil in a tank in the foundation, whence it is delivered by a pump to the vaporizer, also under pressure, the charges of oil being regulated by a

governor; unlike the Priestman, however, the firing of the charge is effected by an ignition tube heated by a blowing arrangement and oil flame, worked from the afore-mentioned pump.

The specification of this engine mentions a timing valve, but as this is not clearly shown the writer cannot describe it.

These engines have also been applied for various purposes, and the makers claim for them great efficiency and economy.

The Hornsby-Akroyd Oil Engine.

This engine is of somewhat similar appearance to those already described. It has the two valves at the end of the cylinder, as in the Priestman engine, with this difference, that both these valves are opened by levers, actuated by cams from a counter-shaft driven from the crank-shaft by bevel wheels; it also differs from both the previous engines in the firing of the charge, the vaporizer is heated in the usual way by a lamp to get the engine started, after which the makers claim that the vaporizer is kept at a sufficient heat by the explosions which take place in it to fire the succeeding charges.

The oil in this engine is also forced into the vaporizer by a pump, and the speed of the engine regulated by a Porter governor, controlling the oil supply to the vaporizer. These engines are also in extensive use.

The Rocket Oil Engine.

This engine, though similar in many respects to those already described, has some very important points of difference; it is precisely similar in so far as it works on the well-known four cycle system, and in having its cylinder and explosion chamber surrounded by a water jacket, the water

explosive gas from the vaporizer through this valve. As the piston gets to the end of its stroke the valves close, and the piston returns and compresses its imprisoned charge; having arrived at the end of its compression stroke, the timing valve H (Plates XXIII. and XXVII.) opens, and the charge is fired by the porcelain tube J (Plate XXVII.), and the explosion drives the piston on its second outward stroke, the exhaust gases being expelled through the exhaust valve K (Plates XXIII. and XXVI.), which is opened by its cam at the proper moment and the cycle is complete. 1st, suction, drawing in the charge; 2nd, compression; 3rd, explosion; 4th, exhaust or expulsion. A third graduated air valve is placed at F to allow of an extra supply of air being admitted after the engine has been started, this makes a richer gas and thus economises oil.

One great point of difference between this and other oil engines is that in this the whole of the air and oil admissions are under separate and perfect independent control, so that any change of temperature or atmospheric conditions can at once be compensated for, by regulating the supply of air, giving a little more or little less as circumstances may demand. This is a very important point in an oil engine, where the quantity of air requisite to form with the oil gas an explosive mixture, depends very much upon the temperature and other atmospheric conditions. Another very important point of difference is that in this engine there are no force pumps, indeed no pumps at all. This is an undoubted step in the right direction, as casualties have occurred from oil tanks bursting under pressure from these pumps; the whole of the air and oil in the Rocket engine is drawn from the tank and through the vaporizer and valves by the piston on its outward stroke.

Yet another very important advantage is the addition of the timing valve; this valve is worked from its own cam, and, being only opened at the proper time, ensures the explosion taking place at the right moment, just after the crank has got over the dead centre, this ensures absolute positive action, and obviates any trouble or uncertainty in the starting of the engine.

The starting of this engine is very similar to the others described, except there is no pressure put on by force pumps; the vaporizer is warmed up by the lamp, and, after a few turns of the fly-wheel, the valves admitting oil and air having been opened, the piston draws in a charge, compresses it, it is fired and explodes, and the engine is started; this can be done in from six to fifteen minutes according to the temperature.

This engine has been used for a variety of purposes—pumping, hoisting, driving the machinery in fitting shops, and in electric lighting, etc.; it is

to be employed also for boring out the stern posts in a large shipyard, as well as for drilling, etc., on board ship during the fitting of machinery.

The following are some of the results of trials of these engines in the makers' yard and in actual work:—

2 N.H.P. Engine Tried in Makers' Yard.

	No. 1.	No. 2.
Mean effective brake load (lbs.) ...	60	70
Revolutions per minute	224	238
Mean pressure in cylinder (lbs.) ...	45	52·48
B.H.P.	2·6	3·237
I.H.P.	3·46	4·27
Engine friction	·86	1·033
Mechanical efficiency	·75	·76
Oil used per hour (pints)	2·9	4·5
„ „ B.H.P. per hour (pints)	1·115	1·39
„ „ I.H.P. „ „	·838	1·05
Quality of oil	Royal Daylight.	Royal Daylight.
Price per gallon	5d.	5d.
Cost per B.H.P. per hour	·72d.	·87d.

1 N.H.P. Engine Tried in Makers' Yard.

	No. 1.	No. 2.
Mean effective brake load (lbs.) ...	47	34
Revolutions per minute	228	228
Mean pressure in cylinder (lbs.) ...	51·1	—
B.H.P.	2·08	1·5
I.H.P.	2·66	—
Engine friction	·58	—
Mechanical efficiency	·78	—
Oil used per hour (pints)	3	2½
„ „ B.H.P. per hour (pints)	1·44	1·7
„ „ I.H.P. „ „	1·12	—

		£ s. d.
Cost of engine, dynamo, wiring, etc.		145 0 0
7½ per cent. interest on above	£10 17 6	
Lamp renewals, etc.	4 0 0	
		14 17 6
Paraffin—2 pints per hour, at 5d. per gallon ...	d. 1·25	
£14 17s. 6d. ÷ 1,660 light hours	2·15	
Total cost in pence per hour	3·4	

Total number of 16 candle-power lamps = 17.

$$\frac{3{\cdot}4}{17} = {\cdot}2\text{d. per lamp per hour.}$$

$$\frac{3{\cdot}4}{17 \times 16} = {\cdot}0125 \text{ per candle-power per hour.}$$

That is less than ¼d. an hour for each 16 candle-power lamp, or 80 candle-power per hour for 1d.

Objection is sometimes taken to oil engines on the ground that the exhaust from them is obnoxious.

A sample of the exhaust gases was taken from one of the Rocket oil engines in December, 1893, by Messrs. Pattinson, the analytical chemists, of Newcastle, and the following is a copy of their analysis:—

	By Volume. Per Cent.
Nitrogen	84·1
Oxygen	7·2
Hydrogen	nil.
Heavy hydrocarbons	"
Marsh gas	"
Carbonic acid...	8·5
Carbonic oxide	0·2
	100·0

From this analysis it will be seen that the combustion is of such a nature that the deleterious gases left are a very small fraction indeed; but should it be intended to place the engine in any confined situation, where even this small fraction would be objectionable, then a patent scrubber is supplied, through which the exhaust is conducted, and which effectually precipitates the obnoxious gases, and passes them off in a perfectly harmless state.

The petroleum oils used for these engines, while varying in quality, must all be safe oils—that is, not easily inflammable—otherwise the danger attending their use, and the restrictions placed upon the handling and storing of inflammable and highly-explosive oils are such as would render the oil engine practically valueless. As the engines are designed, however, they work well with oils of such great specific gravity and high flashing point as to render them perfectly safe and free from vexatious restrictions.

The oils most commonly used are:—

	Specific Gravity.	Flashing Point.	Price per Gallon.
		Degs. F.	
Russolene	·822	86	—
Ordinary petroleum	·802	152	—
New York fuel oil...	·818	218	1¾d.
Ordinary lamp oil	·8	100	—
Common petroleum, including heavy Scotch oil	·82	150	—
Trinity lighthouse oil (light)	·8	155	—
Trinity lighthouse oil (heavy)	·828	258*	—
Tea Rose	·795	76	—
Water White	·78	108	—
Royal Daylight	·79	83	—

* Closed.

These are all safe oils, and in common with Russolene, Royal Daylight, and other oils of that class may be obtained in any quantity and at any part of the civilised globe.

Comparison of Cost of Working with Coal, Gas, and Oil.

Taking coal at 15s. per ton = ·08d. per lb.,
" gas at 2s. per 1,000 = ·024d. per cubic foot,
and " oil at 5d. per gallon = ·625d. per pint.

Then the relative economy is as follows:—

	Per I.H.P. per Hour.		Per B.H.P. per Hour.	
	Quantity of Fuel.	Cost in Pence.	Quantity of Fuel.	Cost in Pence.
Large condensing steam engine ..	2 lbs.	·16	2¼ lbs.	·18

on other work at least 7 hours out of 9; this, added to the cost of oil, makes a total cost of only 5·5d. per hour, or little more than half the cost of the steam engine of the same power.

The great advantages of the oil engine, however, are that it requires no boiler, very little attention, can be moved easily and set down anywhere in the works or elsewhere to drive any special machine; it can be readily started, and when stopped no consumption is going on; the fuel for it is easily obtainable anywhere; there is no smoke, and no ashes or refuse to cart away. These, with other advantages, combine to recommend the oil engine to small power users as the best motor extant for their purposes.

The indicator cards (Plate XXVIII.) are correct copies of those taken on the trials in the maker's yard already alluded to.

In conclusion, the writer desires to express his thanks to Messrs. Priestman Brothers, Messrs. Crossley Brothers, Messrs. Hornsby & Sons, Limited, and Messrs. Robert Stephenson & Co., Limited, for their kindness in placing at his disposal the data and opportunities of obtaining the same, which he has used for the purposes of this paper.

DISCUSSION.

Mr. G. W. Sivewright, in opening the discussion, said he was pleased to welcome a paper of this description. He thought it was highly desirable they should have as much information as possible upon oil engines, as he was afraid many of the manufacturers in this part of the country had not had much experience with these kinds of motors. He had examined one oil engine and was pleased with the ingenious manner in which the whole thing was worked, but the electric battery for igniting the vapour appeared to him to be objectionable, and he was glad to learn in one of the engines commented on in the paper they had been able to get over this. In connection with the comparisons of costs in working these engines, they look very economical on the first statement, but he would like to know if there was any trouble in connection with the cleaning of these engines? He had had considerable experience with patent lights worked by heavy petroleum oils, and although the makers of these lights quoted the low cost per hour each light could be burnt, yet the cleaning of the lamps was most expensive; and if the cleaning was put on to the cost of the actual consumption of oil, instead of these lamps being

cheap they were really dear, as the residue from the oil was so difficult to get out of the burners. They were told there was little or no smoke from the exhaust gases of these engines, and from an examination of the analyses there seemed to be little or no residue; but what he (Mr. Sivewright) would like to know, if there was no residue from the smoke or gases, was it left in the engine, and if such was the case would the engine require to be frequently cleaned out? As far as he understood, the engine had not been made of any big power yet, and he hoped before the discussion ended that some of the gas engine makers would compare the cost of working with the oil engines. He noticed from time to time that small motors, more especially with launches, etc., with oil engines were doing good work, and he was of opinion that, for small motors, where coal and gas were difficult to get, the oil engine was really filling a very useful purpose.

Mr. D. Andrew said he had listened with pleasure to the paper on oil engines, and he agreed that it was a subject which ought to open up a great amount of discussion. He thought it would be too much to enter fully upon it that night. There was one thing in the paper he should like Mr. Stafford to clear up, that was the mode of regulating the speed. There was nothing mentioned about driving it fast or slow as might be required. Also, he should like Mr. Stafford to show to what speed the engine could be driven, what were the number of revolutions, could it be attached direct to a centrifugal pump or ventilating fan, or anything requiring to be driven at a great speed without the aid of belts to get up the speed?

Mr. H. WITHY was very much obliged to Mr. Stafford for bringing forward this paper. The writer stated the engines were useful to users of small power. Now, he fancied very few of those present had to do with small powers, and if large powers had been dealt with they would have been more ready to discuss it. He would like a little information. "A third valve, a graduated air valve," was mentioned. He did not quite understand whether it was put there for use in different states of the atmosphere, *i.e.*, different heights of the barometer. It was difficult to see for what purpose an extra amount of air was allowed. How could it make a richer gas? Then with regard to starting the engine, the writer said it took from six to fifteen minutes; he imagined an ordinary shipyard man would take a hammer to it if he could not start it in less time than that. He could not see why, after the explosion had taken place, 10 per cent. of oxygen was left. Would not all the oxygen be consumed? The question of cleaning was a very important one. There were a great many valves about it. In the hands of a man who did not understand it, he should think these might be very difficult to work. Apparently no economy was claimed over the gas engine, they had therefore to think whether a gas engine was more suitable or more easily worked than an oil engine. From the paper he should take it that the advantage would be in favour of the gas engine. The writer spoke of a man working two hours out of the nine at the engine. They did not find that the gas engine required nearly so much attention as this.

The further discussion of the paper was adjourned.

Vote of Thanks to the President.

Ald. T. Richardson, J.P., said in response to what he knew to be the unanimous wish of the Hartlepool members of that Institution, he ventured to trespass upon the time of the meeting for a few moments and propose a cordial vote of thanks to their worthy President. Mr. Fothergill had hoped to be present, and he could have spoken more of the feeling that prompted this motion, but no one could have greater pleasure in doing it than he had. He did not presume to speak on behalf of the members of the Institution, as this would be done on a more suitable occasion, but in proposing this vote he desired on behalf of the Hartlepool members to place on record their appreciation of the great attention which the President had paid to the meetings of the Institution held in Hartlepool during his term of office, and the uniform courtesy with which he had always treated them; and his successor would find it no easy task to excel him in that respect.

Mr. H. Withy seconded the vote of thanks. He was not, he said, a good hand at paying compliments, and perhaps Ald. Richardson had said as much as was necessary in that way. He, however, heartily endorsed his remarks. The Hartlepool members did feel that the President had paid more attention to the meetings at Hartlepool than, perhaps, some of the Past-Presidents, and they were exceedingly grateful to him for it, and also to the members from Newcastle and Sunderland who took the trouble to come to Hartlepool.

The resolution was adopted by acclamation.

The President said the hearty manner with which they had received the proposal made it quite plain to him that it met with their approval

"MERCANTILE MARINE ENGINEERS."

Reply to the Marine Department of the Board of Trade.

In accordance with the resolution passed at a Special General Meeting of the Institution held in Newcastle-upon-Tyne, on January 30th, 1894 (see page 202) the following letter was sent by the Council to the Marine Department of the Board of Trade :—

Newcastle-upon-Tyne,
April 7th, 1894.

To the Assistant Secretary,
Board of Trade (Marine Department),
Whitehall Gardens, London, S.W.

Sir,

In reference to your letter of the 19th October, 1893, inviting observations by the members of this Institution upon a letter received by your Board from the Institution of Marine Engineers, London, recommending certain alterations to the Board of Trade present regulations relating to marine engineers.

We beg to inform you that the subject-matter contained in the letter of the Institution of Marine Engineers was discussed at length by this Institution in General Meeting, the discussion lasting over several nights. The Council of this Institution desires to offer the following observations as embodying the opinions of the majority :—

1.—Every person who presents himself for the first time at a shipping office to sign articles as junior or assistant engineer shall prove to the satisfaction of the shipping master, by documentary evidence, that he has served a five years' apprenticeship [*or not less than three years' apprenticeship and two years as improver or journeyman*] on the making or repairing of engines (not necessarily marine), and that during at least two years of such services he shall have been engaged at "erecting" or "fitting," or "working on board steamers at the propelling machinery;" and that service in the drawing office shall count full time.

2.—That a third class certificate should be granted, but it is desirable this certificate should not be compulsory to all engineers.

3.—All foreign-going steamships carrying four or more engineers, or in all steamships of 300 N.H.P. and upwards, the third engineer shall be a certificated engineer.

4.—A candidate for a third class certificate shall have served twelve months at sea.

5.—A candidate for a second class certificate shall have served *two* years at sea instead of *one* as at present required.

6.—Clause (*b*), paragraph 35, in the Board of Trade regulations to be annulled.

ROBERT THOMPSON, *President.*
JOHN DUCKITT, *Secretary.*

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893-94.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, SUNDERLAND, ON WEDNESDAY EVENING, APRIL 11TH, 1894.

ROBERT THOMPSON, ESQ., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in West Hartlepool, on March 17th, 1894, which were approved by the members present, and signed by the President.

VISIT TO THE CONSETT IRONWORKS.

The PRESIDENT, in calling upon the Secretary to read a letter received from Messrs. The Consett Iron Company, took the opportunity to express regret at the death of Mr. Evans, the secretary of the company. He had only been a few days ill and had died very suddenly. He (the President) thought the Secretary should express the sympathy of that meeting with the members of Mr. Evans's family in acknowledging the invitation of the company.

The SECRETARY read the following communication :—

CONSETT IRON COMPANY, LIMITED,
BLACKHILL, CO. DURHAM,
March 15th, 1894.

Robert Thompson, Esq.,
North Sands Shipbuilding Yard,
Sunderland.

DEAR SIR,—Mr. Jenkins has handed me your letter to him of the 10th inst., in which you convey the desire of the North-East Coast Institution of Engineers and Shipbuilders to visit Consett during the coming summer.

I very much regret that in his present impaired state of health Mr. Jenkins does not feel equal to taking up this matter with you himself, but it gives me great pleasure, on his behalf and on the part of the Consett Iron Company, to assure you that they fully appreciate the compliment paid by the North-East Coast Institution in desiring to come to Consett in order to inspect the works, and in cordially inviting them to do so, and, should they decide to make this visit, the utmost endeavours of the officials of the company will be put forth to render it interesting and agreeable.

So far as we at present view the matter we have no very decided preference as regards the time which would be convenient. Probably somewhere about July would be found to be suitable, but perhaps this might be left for arrangement later on.

Meantime, if there is any other information which I can afford you kindly command my services.

Believe me, dear Sir,
Yours faithfully,
For Consett Iron Co., Limited,
GEO. AINSWORTH.

The SECRETARY (Mr. Duckitt) said he had been to Consett and had seen Mr. Ainsworth, and although they did not arrange definitely, it was agreed that if nothing occurred to alter it the visit should be made on or about the second Thursday in July. He might say that by command of the Council he had written accepting the invitation and thanking the company for it.

THE BOARD OF TRADE AND MARINE ENGINEERS.

The PRESIDENT said he had to inform the meeting that a reply had been sent to the Board of Trade with reference to the circular respecting marine engineers. It would be remembered that after the matter had been discussed in Newcastle it was resolved that the Council draw up a

NOMINATIONS FOR THE COUNCIL.

The PRESIDENT stated that, in accordance with Article X. of the Constitution, the following gentlemen would retire from the Council :—President—Mr. Robert Thompson ; Vice-Presidents—Messrs. J. R. Fothergill, John Price, and John Tweedy ; Council—Messrs. H. Macoll, D. B. Morison, J. W. Reed, M. Sandison, and Prof. R. L. Weighton, M.A.; Hon. Treasurer—Mr. G. E. Macarthy.

In accordance with Bye-Law 11, the PRESIDENT, on behalf of the Council, nominated the following gentlemen, to be balloted for, to fill up the vacancies :—President—Alderman Thos. Richardson (Hartlepool) ; Vice-Presidents (three to be elected)—Messrs. J. R. Fothergill, H. Macoll, D. B. Morison, and Prof. R. L. Weighton, M.A. ; Council (five to be elected)—Messrs. P. Phorson, G. Renwick (Associate), H. Rowell, A. G. Schaeffer, G. W. Sivewright, and J. E. Stoddart ; Hon. Treasurer —Mr. G. E. Macarthy.

Mr. A. G. SCHAEFFER nominated Mr. J. M. Rennoldson (South Shields) for the Council, and there being no other nominations the list was closed.

The SECRETARY expressed the hope that members would not neglect to send in their ballot papers. Some 800 were generally sent out, and they only got back from 120 to 150.

Mr. W. BELL'S reply to the discussion on his paper, "On a New System of Construction for Large Vessels of Cellular Type," was taken as read.

Mr. W. STAFFORD replied to the discussion on his paper on "Oil Engines."

The SECRETARY read a paper by Mr. Arthur Liddell on "Bases for Classification of Vessels Proportioned to their Strength to Resist Bending and Vibration."

MR. WM. BELL'S REPLY TO THE DISCUSSION ON HIS PAPER "ON A NEW SYSTEM OF CONSTRUCTION FOR LARGE VESSELS OF CELLULAR TYPE."

Mr. Wm. Bell (Liverpool) sent the following reply to the discussion on his paper :—

In venturing to submit his system of construction to the judgment of the great North-East Coast Institution, the author expected adverse criticism, but was not prepared for the chorus of disapproval provoked by his temerity. To quote Mr. Macoll, he had been fired at from all directions, and even denied his claim to originality in the suggested modifications. An attempt to stem such a torrent would require more time than the author is able to afford, and he can only deal with a few of the principal objections.

Mr. Millar opens fire, and gives the range to succeeding marksmen in a speech of great comprehensiveness, hitting everything and missing nothing except the two points of the greatest importance, viz., the question of improving our present system of templating and manipulation and the question of reducing the riveting by making one rivet do the work of two or three. He begins by stating that "Lloyd's might object seriously to several of his (the author's) proposals." This is true, but he adds "that several of them have been carried out in vessels now in active service." If this is so, the practicability of several of these proposals has been demonstrated, and the objection as to classification answered. Mr. Millar says the proposed keel is no improvement on the ordinary slab keel either for strength or efficiency. The distinction between strength and efficiency in this connection is not very clear, but letting this pass, the lateral strength of a slab or bar keel depends altogether on the thickness of the keel plates in the throat of the flange. The thickness of the bulb angles in the same place would be much greater, and it is reasonable to assume that therefore the lateral strength would be increased. Mr. Millar's practical knowledge will readily enable him to perceive why the proposed form of keel would be cheaper than the present combination of slabs and flanged keel plates. Mr. Millar is unable to see how the register tonnage can be reduced without loss of stowage capacity, and is

answered by Mr. Arnison, Jun. The writer would recommend Mr. Millar to consult some practical stevedore on this question before traversing a statement deliberately made after careful enquiry and investigation. The proposal to twist the frames at the ends instead of bevelling them, according to Mr. Millar, "would suit everything except the beam connections." What is to hinder the ends of the channel beams being set back to stand square to the curvature of the ship's side, and so "come in" with the twisted frame? Mr. Millar says the proposed structure of floor has been carried out already, only "in a more efficient manner." He, however, admits that an efficient double bottom can be constructed in the manner proposed much lighter than with ordinary solid floors, although denying the writer any credit for the suggestion. But Mr. Millar is not satisfied with the connection of the intercostal angles on shell and tank top to the T struts on the floors. Here he thinks three $\frac{7}{8}$ rivets at each end of the vertical flanges of the intercostals insufficient. Let him look at the section (Plate XVI.), and he will see that in place of three $\frac{7}{8}$ rivets at top and bottom, making six rivets in all, the same attachment of intercostal to floor is effected by five $\frac{3}{4}$ inch rivets. The system of templating and multiplication of interchangeable parts, which the writer considered of great practical importance, and was at some pains to describe at length in his paper, Mr. Millar dismisses in a sentence or two, evidently without even trying to understand it. Mr. Millar next delivers himself on the rivet attachment with his usual severity as follows:—"The riveting of the longitudinals to the main frames was totally inadequate, even if the longitudinals had not been called upon to do any work, but angle lugs having three rivets through the frames and two rivets through the longitudinals could hardly be looked upon as an efficient connection for 12 inch bars." Does Mr. Millar mean by "longitudinals" the intermediate T or angle pieces forming the web of the side girder? If so, these pieces are not 12 inch but 16 inch, and fitted between the two bulb angles forming the inner flange of the girder as described in the author's paper. The connection of the longitudinal with the main frame is effected by six rivets, two through the inner flange of the frame and two on each side through the horizontal lug pieces on the frame. Is this connection "totally inadequate?" Let him turn again to the section (Plate XVI.) and examine the connection of the enormous side girders in that section with the main frame. Here the attachment consists of four rivets only, although the girders are more than twice the size and weight. Is this adequate in Mr. Millar's opinion? If so, why find fault with the much superior attachment in the section (Plate XVII.

Mr. Millar thinks the writer contradicts himself in many parts of his paper, but he only gives one instance, in the following quotation—"The beam knees are dispensed with as being at best of doubtful structural use." "But," says Mr. Millar, "directly afterwards it was proposed" to fit one or more partial bulkheads in each hold to assist the bulkheads and compensate for the absence of beam knees. According to Mr. Millar, and also in the opinion of Mr. Muir, who follows him, this is contradictory. The writer is unable to perceive any contradiction in the language employed. Would it be a contradiction to say—"Life-belts are of doubtful value in cases of shipwreck. The main dependence must be on the life-boats. It is proposed to dispense with life-belts, but to compensate for their absence and to assist the life-boats, one or more suitable life-rafts will be provided?" Mr. Millar says the area of unstiffened plating is in many places much in excess of the ordinary arrangement, this the writer denies, and would like Mr. Millar to prove his assertion. Mr. Millar doubts whether shell plates fitted as proposed could be templated or punched any quicker or cheaper than in the case of ordinary overlapped plating. If the number of frames are reduced by one-half and there is only a single row of holes in the plate edges, while the seam holes serve for half the longitudinals, is it not clear that time and labour would be lessened in manipulation? That one row of rivets in double sheer is equal to two rows in single sheer, without any allowance for increase in frictional resistance, has been proved by the experiments of Prof. Kennedy. The bulkhead arrangement is condemned by Mr. Millar and Mr. Muir, because "there is no vertical stiffening." What is the very strong air shaft amidships at each bulkhead, extending from tank top to deck and forming part of the bulkhead, but vertical stiffening, and vertical stiffening of a most effectual kind, virtually reducing the area requiring support by one-half. "The connections shown on the various plans are in most cases," Mr. Millar says, "out of all proportion to the sections of material proposed." In the opinion of the writer every separate part in his system is more efficiently connected than the same part in the section to Lloyd's rules. The question of rivet attachment need not remain in uncertainty, it admits of exact calculation and accurate comparison. Let Mr. Millar show by figures where any part of the structure in the section (Plate XVII.) is less efficiently connected than the corresponding part in the section (Plate XVI.), and the author will gratefully accept the correction and acknowledge his mistake. The system of ventilation does not escape the blunderbuss of Mr. Millar. It is not a safe system, because it is possible

the well may be filled with water and the water may rise high enough to flow out of the pipes at the upper turn of bilge and so damage cargo. Now, surely any candid person would admit that a ventilator opening into a large watertight receptacle fitted with steam pumps is preferable to the same ventilator opening directly on to the cargo. Is not such an arrangement practically safe in bad weather? If a constant circulation of air can be maintained between the cargo and sides and decks of the vessel, will not "sweating," the main cause of damage to cargo, be prevented? The opinions of experts in ventilation is entirely with the writer on this point. Lastly, Mr. Millar and others who follow him point out the difficulty and expense of procuring the heavy sections of material required for this system of construction, which he previously told us has been carried out already in most particulars in existing vessels. But Mr. De Rusett says that his firm had no difficulty in procuring 15 inch channel bars, and therefore it is very probable that other large sections may also be got with equal ease when wanted.

Mr. Muir complains that builders have not got tools to deal with the sections of material introduced. This has nothing to do with the merits, good or bad, of the proposed constructive scheme. He also imagines there is a contradiction between what is stated on page 221, paragraph 2, respecting the weakness of the floor bar, and what is said farther on of the stringer plate attachment—which Mr. Muir calls a similar arrangement. There is absolutely no similarity between the floor and stringer plate modifications. In the stringer plate modification the "chock bit" is merely made wide enough in the flange to take the row of rivets on the stringer bar, and so save a row, the value of the attachment remains precisely the same as with the scored out plate and narrow bar. The only difference being that the rivets are farther inboard and easier got at, wherefore the writer

without any resulting gain in strength or economy. 50 per cent. of the frame rivets through the shell are 3-ply, about 20 per cent. of the rivets on the inside shell butt straps and in overlapped butts are 3-ply. The rivets through the bulkhead frames are 3-ply, and in way of the keelson lugs 5-ply. The keel rivets in slab keels are 5-ply and so on. In none of these instances can it be said that the number of rivets required for fastening the parts together are reduced by the increase in number of plys. Therefore as it is more difficult to make good work with three or more plys than with two it may fairly be said that in these and all similar cases, 3-ply riveting is objectionable. But the difficulty of making good work is not in itself a sufficient objection to the use of 3-ply riveting, providing advantages arise therefrom to counterbalance the extra care required to secure good workmanship. It would be no argument against the use of triple expansion engines to say they are more complicated and expensive to make than simple high pressure ones. Now, in the system of construction under review, 3-ply riveting is introduced for a definite and two-fold purpose, firstly, to double the efficiency of the seam rivets by placing them in double sheer and so make one row equal in strength to two rows, and, secondly, to still further reduce the number of rivets required by making the seam rivets serve for attaching the side girders. If the rivets are counted for a given length in both sections it will be seen that by the means indicated, with the same pitch in both cases, a saving of more than 30 per cent. in the number of rivets is effected.

Mr. De Rusett objects to "the unusual number of pockets for dirt formed by the stringers." These "pockets," it should be remembered, are all perforated with holes, and so would be more easily cleaned out than if the bottoms were solid. But let Mr. De Rusett compare the two sections and he will find that, in this objectionable feature, there is little to choose between them. In the section (Plate XVI.), in a length of 26 feet, there are 39 side pockets in the hold on each side, 24 inches by 9 inches by 6 inches, and three troughs formed by the side keelsons, each 26 feet by 15 inches by 6 inches, the collective cubic capacity is 45 feet. In the proposed section there are in the same distance 36 pockets, each 4 feet 4 inches by 12 inches by 4 inches = 46 cubic feet, so it appears that in number and in collective cubic capacity the receptacles for dirt are much the same in both sections.

The President says that "the joining of the plates edge to edge to be of any use must fit close." Why? Do they fit close when overlapped? Will not two plates connected together by a strap and rivets be as strong

half an inch apart as the same plates would be if attached by a wider strap and say 4 feet apart? What are the inside strakes in ordinary shell plating but wide straps connecting two strakes of plating, having their edges 4 or more feet apart.

Mr. Sivewright very justly observes that in the old system of bracketed floors, long since discarded, "there was a difficulty in getting exact workmanship, and the floor being in so many pieces delayed the work considerably. But there is an important difference between the form of floor proposed in the paper and the bracket floor referred to by Mr. Sivewright. In the bracket system the top and bottom members of the floor girder were in short pieces fitting between the bottom longitudinals and attached to them by bracket plates, hence the floor had to be fitted piecemeal and riveted in place and there was very great difficulty in keeping the bottom fair. In the proposed floor there is no such difficulty as the top and bottom members are in one piece and the whole floor can be completed and riveted before going into place like a plate floor. This was fully explained in the writer's paper. There would be no such difficulty as Mr. Sivewright imagines in setting 12 inch channel frames, 7 inch and 8 inch channels are now constantly used for framing by Harland & Wolff and other builders of large vessels, and turned without the smallest difficulty, indeed one of the advantages of this section in regard to manipulation is that, unlike angles or bulb angles, it contracts equally while cooling and does not require "truing up cold," as Mr. Sivewright supposes. It should not be forgotten, when reckoning up the cost of framing, that only one-half or less than one-half of the side frames are required in this system, and that the longitudinals supplying the place of these frames do not need to be furnaced. The cost of producing framing of this description was most carefully gone into by the writer, assisted by

or nearly so, the templates can be applied with the certainty of securing absolute correctness. There would be no landing holes to drill or frames to sheer for the plate edges, and everything would be brought exactly to its place by the longitudinals. In point of fact it is the practicability of accurately templating the frames and longitudinals in the way and by the means described in his paper, that constitutes, in the writer's judgment, the most important practical advantage of his system, and it is a matter of keen regret that none of his critics have realised its economic importance. Both Mr. McGlashan and Mr. Macoll, in unison with other speakers, object to the single-riveted plate seams butting on the longitudinals, and think the connection is insufficient and the proposed innovation undesirable. The writer has already given what seems to him good reasons in favour of this arrangement, and can also quote the opinion of the late Prof. Jenkins in his favour, who publicly stated on one occasion, that so far as efficiency of connection was concerned, single-riveted plate edges were sufficiently strong for any vessel when the further attachment afforded by the frames was taken into account. But with single rivets in double sheer there can be no doubt whatever as to the sufficiency of the connection, for the strength of the joint so made is, for all practical purposes, much greater than an ordinary overlapped joint double-riveted. The correctness of this assertion may be verified at the testing machine, where experiment will prove that, not only is a single-riveted double strapped joint equal in ultimate strength to a double-riveted overlapped joint with rivets of the same diameter and pitch, but also that the point at which visible slip commences is greatly extended in the former case. It is stated in his paper that the true measure of strength in a riveted joint is its power in resisting movement, and the great increase in this power of resistance to movement which the double strapped joint has been proved to possess, justifies its use in the judgment of the writer. For the kind remarks and friendly criticism of Mr. Macoll and Mr. McGlashan the author returns his sincere thanks. He is sorry to find his proposals have met with so little encouragement from those members who have done him the honour to discuss them, but hopes that other members may be more successful, and may not be deterred or discouraged by the reception accorded to his paper. There can be no doubt that mechanical shipbuilding admits of improvement in many ways. The importance of the work, the value of any economic modification to a maritime nation like ours is incalculable, the introduction of any change is beset with difficulties, and rapid progress cannot be expected until the pressure of foreign competition compels more general attention.

The PRESIDENT had pleasure in moving that the best thanks of the Institution be given to Mr. Bell for the paper. Original papers of this kind, which provoked discussion, were the kind they liked, as they brought out information of a useful character, and made the meetings more interesting.

The vote was duly accorded.

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MR. WM. STAFFORD'S REPLY TO THE DISCUSSION ON HIS PAPER ON "OIL ENGINES."

Mr. Wm. Stafford, replying to the discussion on his paper on "Oil Engines," said Mr. Sivewright mentioned the electric battery for ignition. This, as they would know, was applied to some of the oil engines, but, like Mr. Sivewright, he was not in favour of it for this reason, so many things in connection with it were likely to go wrong. At the starting of the engine, should there be any condensation or vapour about, and the electrodes got wet or even damp, then the sparking becomes very uncertain, if not impossible, while an ignition tube was certain in its action, not dependent on chemicals, and understood by any one who might be working the engine. With regard to cleaning the engines, there was no trouble whatever, that was if ordinary petroleum oil, such as "Royal Daylight," "Tea Rose," or "Russoline," were used. Of course, if heavy hydrocarbons were used, such as were used in the patent lights, then there would undoubtedly be a considerable residuum, which would require careful and constant attention to keep clear of; but the same might be done with the steam engine. They might oil their engine with such oils as would, in a very short time, gum up and score and destroy their working parts, therefore they did not use these oils. So with the oil engine, and when oils such as he had mentioned (Royal Daylight, etc.) were used there was very little trouble indeed. The vaporizer might be cleaned out once in six weeks, the valves and tubes cleaned at the same time, while the piston might be drawn, and the cylinder, etc., cleaned once in three months, certainly not oftener, the residuum being so small.

Mr. Andrew said he would like to know about regulating the speed, and also to what speed the engine could be driven. The speed at which these engines were usually driven varied from 170 revolutions per minute in the large engines to 250 revolutions in the smaller sizes; but these could be varied up to about 300 in the latter case, if necessary, and the larger sizes in proportion. The regulation of the speed in the engine with which he was best acquainted, viz., the "Rocket" oil engine, was accomplished by a very neat little governor at the admission end of the engines. This was regulated by a small screw turned by the finger and thumb, which released or tightened a spring controlling a finger piece

which constituted the governor. This could be regulated by turning the above-mentioned screw, so that the engine would run perfectly constant down to any number of revolutions as low as about 60 per minute, of course in this engine as in the steam engine, reducing the revolutions reduced the power.

As far as regarded fouling, Mr. Loveridge was replied to in the above; but with regard to coals at 15s. per ton, this was not excessive nor yet unfair when it was considered that while the steam engine was debited with coal at this price, best Welsh coal was meant, and the oil engine at the same time was charged with best oil at 5d. per gallon. They could get inferior coal, so also they could get inferior oil, and when they could get oil as low as 1¾d. per gallon it was manifest that, however low they put the price of coal, they could not approach a reduction like that, so that the balance would be in favour of the oil engine.

Mr. Withy did not think that many present had to do with small powers. He (Mr. Stafford) was not very sure whether it would not be very much to the interest of large power users to have more small power motors in their works and fewer large power. For instance, in a fitting shop, instead of having one large engine to drive the whole of the shafting and machinery would it not be advisable to have two or three or four smaller engines, so that in case of emergency, overtime, holiday time, or when any one class of work was more in demand or request than another, one of these oil engines could be started for that particular work, and that part of the shop kept running alone, instead of driving the whole of the shafting to get the required part kept running? Moreover, in a shipyard or engine works a small portable engine that required no boiler and was easily moved from place to place was a very great acquisition for many purposes. The writer had one just now boring out a stern post 22½ inches diameter in

supplied the air first through a very small pipe. It entered cold or at the same temperature as the atmosphere. The second supply was heated, then the third supply not according to the state of the barometer, but the height of the thermometer. It mixed with the gas already formed, and made a better explosive mixture. If the temperature was 60 degs. they wanted rather more cold air at that point than if the temperature was only 30 degs. Therefore, instead of this being an objection, they considered it a decided advantage in favour of the engine, placing in the hands of the user the power to so regulate the mixture of air and gas as to make the best explosive mixture, and that according to the temperature of the atmosphere. Then Mr. Withy remarked in regard to its taking from six to fifteen minutes to start, that "if the ordinary mechanic could not get his machine started in less time than that he would take a hammer to it." He (Mr. Stafford) did not know the class of men Mr. Withy had, or if they would take a hammer to a boiler if they could not get up steam in less than fifteen minutes. They had precisely the same conditions, but instead of requiring an hour or an hour and a half to get up steam, they could have the vaporizer heated in fifteen minutes and the work went ahead. Then there was a complaint because all the oxygen was not consumed. Mr. Withy could not understand why 10 per cent. of the oxygen was left. Of course if they had complete combustion there would not be any left, and if they were to analyse the fumes that came out of the boiler chimney they would get more than 10 per cent. of oxygen. He did not think that was very much against the oil engine, if they could reduce the waste to so small a quantity as 10 per cent. Then as to the complaint, "there were a great many valves about it." As he had explained, there were only three—one graduated for oil, and the two others for air. Further, it was said, "in the hands of an unskilled man they might be difficult to work." Practically speaking, there were very few valves about it—one to start the engine, and one to put it into atmospheric condition. Again, it was said, "From the paper they might take it to be in favour of the gas engine." Mr. Withy was quite right. The comparison he (Mr. Stafford) gave between oil, gas, and steam was certainly to the advantage of the gas engine; but a gas engine would only work if they had gas pipes leading to it, and before they had gas pipes they must have a gasometer; and if they had gas pipes to move about a shipyard or farmyard, taking it to the field for thrashing purposes, etc., the economy in favour of the gas engine would quickly disappear. "The writer," said Mr. Withy, "had spoken of men working at the engine two hours out of the nine, and that gas engines did not

require so much attention." Well, like everything new, they had got up to a certain point. They had got an oil engine of such a character as to be easily started by unskilled men, an engine they could go to at six o'clock in the morning confident that they could start work with it by half-past six. There was a time when they did not start exactly at the same hour, and sometimes not even on the same day as they were intended to; but that difficulty had been got over. There was only one thing further he would like to say. While they could speak with confidence as to the capability and the usefulness of the oil engine for small powers, there was this difference between it and the steam engine: they had in the oil engine only a small margin of power beyond what was given as the nominal horse-power. They could put down a 10 horse horizontal or vertical steam engine, and know if it did not do the work they could increase the pressure of the boiler, or enlarge the boiler and give a bigger flow of steam and thus increase its effective power; but with the oil engine that was designed to run up to a certain power this could not be done; the power could not be materially increased. They may put down a 10 horse oil engine and be satisfied that it will give out 10 horse-power; but if you put it to do 15 horse-power it will stop; it will not do it, and you must get a larger engine to replace it. This appears to be now the whole secret of the oil engine. Put it down large enough for the work it has to do, supply it with any of the oils mentioned, give it just a little attention, and it will be found, as now constructed, a steady and reliable motor. He thanked them for their courtesy and attention.

The PRESIDENT said it was not a unique thing to receive a vote of thanks for a paper; but it was in Mr. Stafford's case a unique thing to read a paper on oil engines. It was the first read before the Institution

BASES FOR CLASSIFICATION OF VESSELS PROPORTIONED TO THEIR STRENGTH TO RESIST BENDING AND VIBRATION.

By ARTHUR R. LIDDELL.

[Read before the Institution, in Sunderland, on April 11th, 1894.]

The following paper on "Bases for Classification of Vessels" is not intended as an attack on existing classification societies. Their methods and practice are, however, inseparably connected with the subject, and reference will be made to them just so far as is necessary.

In apportioning material to resist the varying strains to which a ship may be liable, it is not possible to start from first principles of "given strain to be withstood and factor of safety," as in structures upon land. The designer must work from the results of experience, and proportion the parts of the proposed vessels to those of others which have proved themselves strong enough at sea; and as first requisites of this, quantities must be found that will measure the relative strains under given conditions of vessels varying in size, proportions, and form.

Though the subject is attended with difficulties, such quantities can be found which will give sufficiently correct results, and the scantling numbers of the classification societies are intended to supply these. Unfortunately the latter do not take variations in form and dimensions sufficiently into consideration, and their application sometimes produces unsatisfactory results.

The most important, because the most considerable, strains to be met are the longitudinal ones, and these are, by common agreement, most severe when a ship is moving over waves of her own length. Sagging and hogging strains then alternate with each other, and are generally most considerable amidships.

Calculations are made by our naval constructors and others for these two kinds of strain with an assumed maximum height of wave, and with the ship regarded as steady on the crest and in the trough of a wave respectively.

Taking a broad view of the circumstances the above assumptions seem the most suitable that can be made, and it is the writer's intention to proceed from them in order to frame a measure of relative longitudinal strain.

Fig. 1, Plate XXIX., shows the profile of a ship assumed as resting, first on the crest, and then in the hollow of a wave of her own length, as shown by the lines C C C and T T T. The centres of buoyancy of the ends may be in the positions X X and Y Y. For the present purpose it will simplify matters to assume the ship supported on points in the middle of her length or at her ends. In the case of merchant ships the sagging strain, *i.e.*, that occurring when the ship is supported at her ends, is generally the less important of the two, because where it comes into play extra strength is afforded by tank top, keelsons, etc.; and the bottom plating, while not cut up by engine and boiler openings, hatchways, and the like, is in itself stronger than that of the corresponding component of the hogging girder, viz., the upper deck.

Let it be admitted that the centres of gravity of the fore and after halves of the laden ship are at the points Z Z. The hogging tendency will be in proportion to the distance Z Z × weight or displacement. The distance Z Z is a quantity varying with the fulness or fineness of the vessel, and, assuming homogeneous cargo, nearly as the similar distance between the centres of buoyancy of the vessel's ends. It is more convenient to work with the centres of buoyancy, and they may be found with sufficient correctness by the aid of Kirk's block (see Fig. 2, Plate XXIX.). The line V E in the figure is halved at the point H and the line K H N is drawn parallel with the base-line S T. Assuming the ends alike full, if V T=1, the prismatic coefficient of the ship will be represented by the distance H N, and the centre of buoyancy of an end-half of the ship will correspond with the centre of the figure E V T A.

If a series of such figures be drawn for prismatic coefficients of say ·5 to 1·0, as in Fig. 3, Plate XXIX., and V T be again = 1, the distance C H of the centre of buoyancy from midships for coefficient ·5 = 0·333

prismatic coefficient, her tendency to hog is in proportion to displacement × 2 × G H, or to displacement × length × ·333.

It must be borne in mind that the moment thus resulting is only proportional (not equal) to the actual moment.

Assuming the worst conditions of sea for all cases, the actual moment should bear some constant proportion to the one thus found, which however our present knowledge of the subject does not enable us to fix. For the present purpose it may be disregarded.

Consider next, the power possessed by the vessel herself to resist bending. The weakest point of a ship longitudinally is at, or near, her half-length, and here the moment to resist bending is proportional to :— Moment of inertia of midship section × ultimate stress on the material ÷ the distance J from the neutral axis to the top or bottom of the girder which is proportional to the depth. In practice it is usual to distribute the material in increasing thickness towards the top and bottom of the girder, and this with such regularity that instead of moment of inertia × stress ÷ depth the moment to resist bending may be taken as proportional to sectional area of material × depth^2 ÷ depth, or to sectional area × depth. The ultimate stress may be disregarded.

The depth might be measured at the middle of the half-breadth.

Bending moment, then, is proportional to displacement × length × coefficient, and moment to resist bending is proportional to area of material × depth; and further, displacement × length × coefficient is proportional to area of material × depth.

Now, area of material is equal to mean thickness × girth, and substituting the latter displacement × length × coefficient becomes proportional to girth × mean thickness × depth. Further, the mean thickness of plating may be set

$$\text{proportional to } \frac{\text{displacement} \times \text{length} \times \text{coefficient C}}{\text{girth} \times \text{depth}},$$

and this, as a basis for scantlings of longitudinal structural parts of vessels of moderate speed and not too shallow draught, is probably as good a compromise between scientific accuracy and practical simplicity as can be obtained.*

An alternative number for very swift and shallow vessels will be considered further on.

Regarding the assumption upon which the above number is based :— That of a vessel at rest alternately on the crest and in the trough of a wave of her own length, it may be objected that the conditions under which she has to work are somewhat different. A ship rising on to the crest of a wave

* See answer to discussion.—Ed.

is subject to a static force proportional to displacement × length × coefficient C, tending to stretch the gunwale and compress the keel and a dynamic force proportional more nearly to displacement × length^2 usually less in amount, tending to counteract the static one, that is, tending to throw the ends up.

The exact converse is the case when the vessel is sinking into the trough. At the same time the virtual weight of the vessel is diminished or increased (as much as $\frac{1}{5}$ sometimes) on the crest or in the trough to a greater or less extent, according as the wave crests are high or low and approach her quickly or slowly. The resultant of these various forces in each case will be proportional to a quantity lying between displacement × length × coefficient C and a number more nearly proportional to displacement × length^2, and as the static forces represented by displacement × length × coefficient C are generally the greater in amount, this may be accepted, for ships of moderate speed and dimensions, as the best measure of longitudinal strain attainable.*

For ships of great speed and shallow draught the dynamic forces may become the more important, and this may entail the substitution of the quantity displacement × (length × coefficient C)^2 for the one just given, as will be shown further on under the head of vibration.

The extent to which freeboard, good form, and consequently speed, are handicapped by the classification societies is not usually realised.

Ships A and B have the same length, displacement, and depth. Ship A has a prismatic coefficient of ·8 and a distribution of its volume largely towards its ends, as shown in Fig. 4, Plate XXIX., by the bluffer curve of sectional areas. Ship B has a prismatic coefficient of ·6 and a distribution of its volume more towards its middle, as shown in the figure by the fine-ended curve.

Plate XXIX., be adopted, the strains on the respective structures amidships will vary as ·5 to ·333, while the strength to resist bending, assuming depth = mean half-breadth, is for the fine ship about $1\frac{1}{2}$ times as great as for the full one.

Theoretically, the plating of the fine ship might be $\frac{2 \times \cdot 333}{3 \times \cdot 5}$, or $\frac{4}{9}$ths* the thickness of the full one. Lloyd's would make it about $\frac{1}{8}$th thicker instead of thinner.

Practical considerations as to bumping, rusting, etc., might prevent the possibility of going to the extreme reduction of $\frac{4}{9}$ths above-mentioned, but it would not be necessary to make the plating of the sharp ship the thicker of the two.

The two preceding examples have dealt with differences in the virtual length of a ship, but the matter does not end here. The classification societies do not take due account of the proportion borne by the actual length to the other dimensions.

Ships P and Q, Fig. 6, Plate XXIX., have the same plating number as per Lloyd's rules. The respective strains on their structures amidships are as—

$$\frac{8{,}000 \times 80}{12{,}000 \times 60}, \text{ or as } 8 : 9;$$

the strains on the fibres of the material as—

$$\frac{600}{400} \times \frac{8}{9}, \text{ or as } 4 : 3.$$

If the depth be varied instead of the breadth the results are still more anomalous.

Ships R and S, Fig. 7, Plate XXIX., again have the same plating number. The respective strains on their structures amidships are as—

$$\frac{8{,}000 \times 80}{12{,}000 \times 60}, \text{ or as } 8 : 9;$$

the strains on the fibres of the material as—

$$\frac{600 \times 8}{250 \times 9}, \text{ more than } 2 : 1.$$

The rules provide for extreme proportions of $\frac{\text{length}}{\text{depth}}$ ranging between 11 : 1 and 16 : 1, and of $\frac{\text{length}}{\text{breadth}}$ ranging between 7 : 1 and $10\frac{1}{2}$: 1.

In ships P and Q the proportions of length : breadth are 3 : 1 and 8 : 1 respectively, for the latter of which Lloyd's would require a trifling increase in the upper-deck stringer and deck plating. In ships R and S the proportions of length : depth are 6 : 1 and 16 : 1 respectively, for

* See answer to discussion for proposed modification in number, by which '$\frac{4}{9}$ths' would become about '$\frac{1}{1\cdot4}$'.—Ed.

the latter of which Lloyd's would require an addition of about $\frac{1}{2}$ to the longitudinal structural parts.

The adoption by Lloyd's of the ship of 11 depths as a standard may be defended on the ground that it gives the smallest scantlings that are desirable in view of rusting, wear, and tear, but here there is room for considerable difference of opinion, and the limit might probably be set a good deal lower.

Bureau Veritas's number for plating shows still greater disproportion.

In Fig. 8, Plate XXIX., the two blocks represent ships having the same numbers, viz.:—$2 \times 2 \times 2 = 8$ and $1 \times 1 \times 8 = 8$ respectively.

The total strains to be borne by the respective structures amidships are as 4 : 1, and the strains on the fibres as 16 : 1.*

The foregoing conclusions may be summed up as follows:—In the opinion of the writer the plating numbers of the classification societies take wrong account of the longitudinal disposition of the displacement, and, as regards the latter, make the thickness of the longitudinal structural parts vary inversely as the strains which they are liable to have to undergo. Further, they do not provide for variation in the proportion borne by the length to the size of the midship section, and the additions for extreme proportions, which are intended to make good this deficiency, are, it is submitted, applied too roughly to be looked on as satisfactory.

Were the static number here proposed adopted, additions for extreme proportions would, it is believed, cease to be necessary, but on account of wear and tear it might be advisable to fix minimum thicknesses of plating for ships of various sizes.

Now that it has become the practice to fix load-lines for all vessels, it becomes feasible to regulate scantlings by displacement as above proposed,

throw the vessel's ends alternately up and down depends on displacement × (length × coefficient C)^2.

It depends also on the speed at which the vessel rides over the waves, and in the case of her steaming against the sea this will be proportional to the sum of the speeds of the vessel and of the waves.

At the same time the time in which a wave crest travels from the middle of a vessel to its after-end is inversely proportional to the length of the vessel, the case of most severe straining (that in which wave-length is equal to length of vessel) being assumed.

Thus the thickness of plating is—

$$\propto \frac{\text{displacement} \times \text{length}^2 \times \text{coefficient C}^2 \times \left\{\begin{matrix}\text{speed of ship} + \\ \text{speed of waves}\end{matrix}\right\}}{\text{girth} \times \text{depth} \times \text{length}}.$$

Now, the length of a rolling wave of the Atlantic is proportional to the square of its speed in knots, and its speed is equal to—

$$\sqrt{\text{length of wave} \times \frac{1}{\cdot 562}},$$

and taking the length of vessel and length of wave as synonymous, the quantity—

$$\sqrt{\text{length of vessel} \times 1\cdot 78}$$

may be substituted for speed of waves.

The speed of an Atlantic greyhound may be roughly reckoned equal to $\sqrt{\text{length} \times \cdot 8}$. Substitute these in the proportional quantity above, then the speed of ship and wave together become equal to

$$\sqrt{\text{length of ship} \times \cdot 8} + \sqrt{\text{length of ship} \times 1\cdot 78},$$

or to $\sqrt{\text{length of ship}}\,(\sqrt{\cdot 8} + \sqrt{1\cdot 78})$,

or to $2\cdot 23\sqrt{\text{length of ship}}$.

In dealing with proportional quantities the factor 2·23 may be neglected, and the proportion becomes:—

$$\text{Thickness of plating} \propto \frac{\text{displacement} \times \text{length}^{1\frac{1}{2}} \times (\text{coefficient C})^2}{\text{girth} \times \text{depth}},*$$

so that, assuming the length proportional to girth and to speed^2, the vibration and thickness of plating necessary to counteract it will vary with (length$^{1\frac{1}{2}}$ × breadth), the other factors of fineness of form and depth remaining the same.

Now, the Atlantic liners are bound by the draught (about 27 feet),

* See answer to discussion. Modified in accordance with alteration to first number, the formula becomes:—

$$\text{Thickness of plating} \propto \frac{\text{displacement} \times \text{length}^2 \times \text{coefficient}}{\text{girth} \times \text{depth} \times \text{draught}},$$

the coefficient approximating to $\frac{\text{coefficient of load water line}}{\text{coefficient of displacement}}$.—Ed.

which admits of their entering and leaving the harbours, and as they increase in size their length and breadth must become disproportionately great. Under these circumstances it is no wonder that the longest and broadest of modern vessels, the "Campania" and "Lucania" should vibrate more than usual.

Compared with one of the longest and broadest of their predecessors, the "City of Paris," with $527\frac{1}{2}$ feet length and 63 feet beam, their tendency to vibrate as due to general proportions, is as—

$$\frac{(600)^{1\frac{1}{4}} \times 70}{(527\frac{1}{2})^{1\frac{1}{4}} \times 63} \text{ or as } \frac{1{\cdot}35}{1},$$

the other conditions being assumed as similar.*

If it be assumed that the thickness of plating (as regulated by the classification societies' rules) divided by the static proportional quantity or number be less in the "Campania" than in the "City of Paris," as is in every way probable, there will be a still greater disproportion in the tendencies of the respective hulls to vibrate.

In still water the vibration caused by the machinery is that which makes itself most felt, and if the revolutions of the screw per minute be kept constant this will vary about as the weight of the moving parts × (radius of gyration)^2, which again is proportional to

$$\text{I.H.P.} \times (\text{I.H.P.})^{\frac{2}{3}} \text{ or to I.H.P.}^{1\frac{2}{3}}.$$

Amongst waves the two kinds of vibration may go on simultaneously, unconnected with each other; but if the periodic time of the hull-vibration happen to synchronise with a multiple of the revolutions of the propeller, the two will, at regularly recurring intervals, act together with correspondingly increased effect. The vibrations due to the working of the machinery have been sufficiently discussed lately, and it appears that

be profitable to note the scantlings of vessels that have at first proved too weak and afterwards been put right by judicious strengthening. Such vessels may then be taken as neither too strong nor too weak for the work they have to do. In general, Lloyd's tables may be looked on as a storehouse of experience. They have been altered and re-altered until they now give scantlings that are at least strong enough for any usual type of ship. For many types they give excessive scantlings, and hence these are not built. If the scantlings there given for the longest, broadest, and fullest ships usually built be taken, they may be accepted as standards, and by the help of new numbers scantlings may be established that are sufficiently strong for all other types.

In regard to other structural parts :—Frames and reverse frames may suitably be regulated by their own length amidships somewhat in accordance with Lloyd's practice.

For the floors the immersed area of midship section × breadth^2 × the frame spacing might be suitable; the immersed area of section × frame spacing representing the proportion of the cargo which might be assumed to rest upon a single floor.

In regulating beams the 'tween deck height and the frame spacing ought to be taken into account as well as the breadth^2, and within limits the dimensions of each beam might be regulated by its own length squared.

The masts and rigging of a modern vessel, considering their work, form one of the lightest structures of the day. For the sake of lightness aloft the margin of safety is reduced to a minimum, and with results that are not always satisfactory.

The tables for these parts, suggested by Lloyd's, and generally adhered to, are practically based upon height of rig and tonnage of vessels, and so long as ships are built to everyday proportions and quantities of sail they give good results. In extreme cases, however, they fail.

If a ship be inclined by a strong gust of wind, the weather shrouds will stretch and the lee ones become slack. The mast itself will first bend at the head to leeward, and then be subjected to a downward strain nearly equal to the pull on the weather shrouds, and tending to twist it into an S-like form.

At the deck it will have a tendency to bend towards the weather side, and the greatest strain will probably be at about half height and similar in character to that of a bow when bent. The strength to resist snapping ought to be in proportion to length of mast × ultimate strength of shrouds on one side. The strengths provided for by the tables are in proportion to (length of mast)^3, the spread of canvas being assumed proportional to (length of mast)^2.

The shrouds themselves are regulated by the tonnage of the vessel. Now, a vessel of given tonnage may have two or three, three or four masts, according to size; she may be broad or narrow; she may have proportionally large cross-sections or proportionally small ones; she may be of full or fine form; and she may have a larger or smaller sail spread. That these disregarded factors all exercise influence on the power of a vessel to carry on sail will hardly require demonstration. In different vessels of the same tonnage the possible strains on the material of the shrouds, as will be afterwards shown, may easily vary as 2 : 1. That the parts going to make up the rigging and its connections often have to approach the breaking limit is proved by the number of vessels every year dismasted.

The strains on a vessel's rigging have been shown by the late Mr. Wm. John in a report on masting made to Lloyd's Committee, to be made up of three parts :—

(*a*) Force of the wind on the sails.

(*b*) Overhanging weight of tophamper.

(*c*) Transverse strain due to rolling.

The addition of these quantities, which vary in amount one with another, according to stowage, sail spread, etc., gives the pull to be met by the rigging. The first of these is proportional to area of sail × height of centre of effort × the square of the cosine of the angle of heel; the second, to weight of tophamper × height of centre of effort (approximately) × the sine of the angle of heel; the third is proportional to the moment of inertia of the tophamper × the angle of roll ÷ (time of oscillation)^2.

In an example of a well-proportioned sailing vessel, cited by Mr. John,

breadth, and depth to one another. As regards the ultimate strength of 4,900 foot-tons, it may be premised that in practice the shrouds may be too tight or too slack, or unequally set up. In this way the shrouds may break in detail, or the mast before the shrouds, or the shrouds may have some of their strength expended on a too tight setting up, and the theoretical ultimate strength not be realised.

The ship taken by Mr. John was one of 1,600 tons gross register, and 267 × 39·3 × 23·3 feet registered dimensions. If the length be decreased and the midship section increased, keeping the proportion of depth : breadth and the tonnage the same, the vessel's power to carry sail is increased, and it may be assumed that a higher rig and a larger sail spread would be resorted to. Without going beyond reasonable bounds, the strains on the mast and rigging, above given, may be taken as increased by $\frac{1}{5}$ and amounting to :—

	Foot-tons.
1	4,900
2	3,980
3	4,330

Again, assume a further alteration in the vessel's dimensions, and make the proportion depth : breadth = ·5 instead of ·6, the power to carry sail will be again increased, and still more the temptation to carry on, as the vessel will be stiffer at small angles of heel. She may be credited with a still higher rig, and her tendency to roll will be very much increased. Again, increasing by $\frac{1}{5}$ the result will be :—

	Foot-tons.
1	5,880
2	4,780
3	5,200

Recurring to the ultimate transverse strength of the mast and its rigging, which, being made dependent on the tonnage, remains unaltered, on account of the different parts not always acting together, as above shown, the figure 4,900 may be reduced by perhaps 5 per cent. The resulting 4,655 foot-tons is less than any of the three assumed total strains for the broad vessel.

Now, it may readily be admitted that the conditions of strain assumed would be met with only in extreme cases, but if the figures taken for the broad vessel be reduced by 25 per cent., they are still dangerously near the ultimate strength of 4,655 foot-tons, and the cases of dismasting, which too often occur, show that conditions something like those assumed are at times realised and ought to be reckoned with in rigging a vessel.

If the proportion of depth : breadth (= ·6 in the original example) be increased to ·65, instead of decreased, the tonnage and the proportion of length to midship section area being kept the same, the ship will become more tender and will have a reduced rig. A low stowage of her weights will give an only moderate G.M. height, and her rolling will in all conceivable cases be moderately slow and easy. She will probably have righting tendency to angles of heel even beyond 90 degs., and carrying on will cause her to heel so far over, that the most reckless captain will take in sail long before the ultimate moment that would cause capsize could be reached. The masts and rigging, then, could be made very considerably lighter than in the calculated example, and this in itself would help to decrease the strains to which they would be liable. The first strain originally given, for a steady pressure of wind, may then be reduced by at least $\frac{1}{4}$ and will probably never exceed 3,000 foot-tons, while the second and third sets of conditions need not be taken into account at all. If the whole sail area of the vessel be spread over four masts instead of three, the strain on the one mast will again be reduced by at least $\frac{1}{4}$ and the 3,000 foot-tons will become 2,250.

To sum the matter up, the writer has, by simply varying the proportions, of the standard vessel while keeping tonnage the same, obtained results for a given steady pressure of wind on the sails of one mast varying from 5,880 to 2,250 foot-tons against an ultimate effective strength due to tabular dimensions equal to 4,655 foot-tons.

It will be evident, then, that the figures in the suggested tables of Lloyd's Register, while useful as standards for well proportioned ships, ought to be increased or diminished for varying proportions of vessels and their rigs by very considerable amounts. If, in addition to the

meter),[2] × cosine of angle of spread. The strength of the mast will then be proportional to that of its rigging. For yards the basis might be :—Length of yard × area of sails attached to it above and below.

As regards the general question, if scantlings were apportioned somewhat on the lines proposed the cost of the sharp ships advocated would be considerably less than that of those now built, and the box-shaped structures so familiar on the North-East Coast would probably disappear.

A vessel to carry, say 1,000 tons at 12 knots for a given distance and with given length and draught might be built (1) to a sharper model than at present; (2) with smaller machinery; (3) with a smaller allowance for fuel; (4) on smaller displacement and smaller weight of hull.

The longitudinal parts of the structure may represent about half the weight of steel in the hull, and assuming such a vessel of full model, with ·8 prismatic coefficient, to be increased in breadth and fined down to ·6 prismatic coefficient, the weight of these parts might theoretically be reduced by 12½ per cent.* On the whole hull this would represent about 4 per cent., and it would bring with it at least a 1 per cent. further reduction due to the decreased weight to be carried. When the reduction in weight of the machinery and coal and the consequent further reduction in the size of hull required to carry it are considered, the writer can hardly be considered too sanguine in his expectation of a 5 per cent. reduction on the total cost of the vessel and its machinery. Probably the reduction would be much greater. It may be remarked that a 5 per cent. reduction on the cost of new shipping in a good year would amount to a million of money.

To designers accustomed to coefficients of ·8, the idea of building cargo boats with yacht-lines may seem a dream, but no man, who goes into the matter, can deny that it is a reasonable one. With given length, draught, and displacement, the broader a ship is made amidships, the stronger becomes the longitudinal girder, and for the classification societies to require thicker plating for the increase of breadth is evidently wrong.

In regard to the proposed plating numbers a few words are perhaps necessary as to girth. This may be taken from gunwale to gunwale round under the bottom, or it may include the upper deck. Probably the latter would be more correct.

The following example may serve to illustrate the general question:—An iron vessel of 285 feet × 36 feet × 25 feet 7 inches moulded had a load draught of 21 feet 6 inches, including a 10 inches keel. With a block coefficient of ·783 her displacement was 4,735 tons. Her deadweight

* Modified by amended number, for which see answer to discussion.—Ed.

carrying capacity was 250 tons of bunker coal, and 2,790 tons of other cargo. Her weights were as follows:—

	Tons.
Heavy forging	23
Plates, bars, and rivet heads	1,095
Smith iron, rigging chains, etc.	48
Wood	99
Cement and tiling	80
Outfit	116
Equipped weight of hull	1,461
Engines, boiler, and water	234
Total equipped weight	1,695

The prismatic coefficient was about ·8. Assuming this reduced to ·6, and referring to the proposed static number, the lever would become shortened in the proportion of ·408 to ·344 (see table on page 288)—roughly as 8 to 7, and this would affect the longitudinal structural parts, which represent about half the weight of plates, bars, and rivet heads, or 550 tons, that is to say:—

	Tons.
These parts might be lighter by	70
A further reduction in machinery required to drive the sharper vessel at the same speed as before, might be put down at	25
Together	95
Against this we may set some increase in the transverse structural parts, say	15
Leaving	80

The displacement now becomes 4,565 tons, and the dimensions of a vessel to give this would be about 285 feet × 46 feet × by 25 feet 7 inches, with a draught of 21 feet 6 inches to bottom of 10 inch keel, a prismatic coefficient of ·6, and a block coefficient of ·589.

The foregoing is an example of the effect of making a vessel broader, and distributing her displacement more towards the middle. Probably it would be more profitable to increase the length a little and the breadth not quite so much. The reduction on machinery and coal would then be rather greater and that on iron rather less.

In regard to the engine power required to drive a fine ship of this size at a moderate speed, there is not much available in the shape of data, and the 10 per cent. reduction above assumed must be taken as a very rough estimate. Perhaps some members can supplement this.

If the same vessel be taken and her freeboard increased by 1 foot, her moment to resist longitudinal bending will be increased (1) in proportion to her depth^2, *i.e.*, by about $\frac{1}{12}$th, and (2) in proportion to the girth of her midship section, *i.e.*, by about $\frac{1}{70}$th. The second increase would allow a slight reduction in the thickness of the plating, but as the girth would be increased in the same proportion, the weight of the longitudinal structure would not alter thereby.

On the other hand, the first increase of $\frac{1}{12}$th in the moment to resist bending will allow a reduction in the weight of the longitudinal parts of 22 tons, and in the total weight of iron of 27 tons, a further reduction in machinery, coals, etc., may amount to 8 tons on the displacement, so that the ship might be 35 tons lighter.

In practice this theoretical reduction would probably not be to the full extent attained, but it is something that with a given draught a ship may be increased by 1 foot in freeboard without having to add largely to her weight, as is the case under existing rules. Whether the possibility of increasing freeboard would be taken advantage of would depend on questions of tonnage as well as on classification rules, the former of which, of course, are beyond the scope of the present paper.

In conclusion, while not wishing to claim too much for the proposals made by him, the writer hopes to have directed attention to some real anomalies in present shipbuilding practice, and to have placed the question of bases for classification of vessels before this Institution in a manner suitable for discussion.

DISCUSSION.

Mr. W. Hök, opening the discussion, said at the outset he must make the admission that his criticism of the paper would be wholly unfavourable. Coming to the very first proposition, viz., that the ship was supposed to be supported on points either in the middle or at the ends, and that the stresses were proportional to the distances between the centres of gravity of the two halves, or, as he for simplicity had preferred to put it, to the distances between the centres of buoyancy of the two halves, it was a wholly inadmissible proposition. By approaching the problem in this manner he took into account only one of the forces that caused the stress, viz., the gravity, and left out the other equally important, viz., the distribution of buoyancy. The result was, among other things, that the influence of fineness became greatly exaggerated. But he would not touch on this point any more in order to save time, for if they would take the trouble to look up the *Transactions** they would find the influence of fineness on stress discussed there. Then Mr. Liddell stated wrongly the fundamental formula on which all calculations of longitudinal strength were based. He said that the moment to resist bending was proportional to the moment of inertia of section multiplied by stress. This should be the moment of resistance of section multiplied by intensity of stress, the moment of resistance of section being the moment of inertia of section divided by the distance of the material in stress from the neutral axis. Of course that made a great difference to the whole thing, for he here omitted, so to speak, the depth of the girder. Then he made the assumption that the moment of inertia multiplied by stress

coefficient C (which coefficient varied with fineness), divided by girth into depth. With this formula the thickness of plating would vary as the square of the dimension, which amounted to saying that if a vessel 100 feet long had $\frac{1}{4}$ inch plating, a similar vessel 400 feet would have plating not less than sixteen times as thick, that was 4 inches thick. But when he took account of the dynamic force he advanced the proposition that the thickness of plating to resist the stresses due to this force should be proportional to the displacement into the length raised to the 1·5th power, into breadth, into the coefficient C squared, divided by girth into depth. This function varied as the 3·5th power of the dimension, which amounted to saying that to resist the dynamic force the plating must be not less than 32 inches thick in a 400 feet ship if they took the 100 feet ship as a basis, or if, instead of the $\frac{1}{4}$ inch plating for the 100 feet ship, they assumed $\frac{5}{8}$ths of an inch as the thickness for a 400 feet ship, the plating of the 100 feet vessel would be $\frac{1}{200}$ths of an inch thick, and that was too thin.* In the same way the frames were proposed to vary as the dimension, the floors as the fourth power of the dimension, and the beams as the square of the dimension. He need not give them any examples of the results that would accrue if they based their scantlings on these propositions, for they could easily work these things out for themselves.† If the question was of varying the fineness, as on page 290, it must be understood that it was because his fundamental formula was so incorrect that he arrived at these extraordinary results of the theoretical thickness of the plating in fine ships. He (Mr. Hök) hoped that no one would go away in the belief that the theoretical thickness of the plating of a fine ship should be $\frac{4}{9}$ths the thickness of that of a full ship. As far as the theory went, it was impossible at the present time to calculate the thickness of the plating of a fine ship compared with the thickness for a full ship; but they knew so much that if there was any difference at all, it was very small, and that was the basis all the registry societies went on. With regard to the part of the paper which referred to rigging and masting, he had not read it through, so he could not say whether it was sound or not. Regarding the latter portion, where Mr. Liddell showed the advantages which would accrue if his system of scantlings was adopted,

* The vibration number is now modified by the writer.—See his reply to the discussion.—Ed.

† As regards frames, floors, and beams, the writer did not mean to formulate numbers, but rather to call attention to points which should be taken into consideration in forming them. The taking of these into account need not conflict with Lloyds' practice of varying the sectional area of frame-bar with the dimension, and of floorplate and beam with dimension^2.—Ed.

he was sorry to say it was throughout based on his principal formula which he (Mr. Hök) had shown to be incorrect. He must apologise for having criticised Mr. Liddell's paper in this manner, but he held very strongly the view that the science taught in an Institution, where they had so many young Members and Graduates should be as pure and correct as possible.

Mr. F. Caws said there was one part of the paper about which he felt no doubt at all, and indeed he was quite sure the writer was right; and that was with reference to a decrease of resistance due to the adoption of forms which the paper advocated. He (Mr. Caws) had tried models which had been sent him and which represented exactly the kind of thing Mr. Liddell advocated, as compared with the ordinary kind of common box shape. It was perfectly astounding the difference in the resistance between these models. Without expressing any opinion on the formulæ, and other parts of the paper, which he felt needed and deserved careful study, he thought that the writer was undoubtedly correct in regard to the great decrease that would be found in resistance if the finer forms were adopted.

Mr. Hök—May I be allowed a word? I wish simply to say that I proved this matter very conclusively in the paper I read some months ago before the Institution. I think Mr. Caws is perfectly correct in what he says.

Mr. Geo. N. Arnison, Jun., said that after what they had heard from the previous speaker, it might be thought the discussion should at once close. The writer of the paper in the latter portion of it had, however, while modestly not claiming "too much for the proposals made by

For instance, considering the question merely of the difference of displacement. In a vessel of 5,000 tons displacement, whose coefficient of displacement was ·8, there are the same scantlings as on a vessel of the same dimensions with ·7 coefficient, although the displacement would only be 4,375 tons, and even the same scantlings as on a vessel of ·6 coefficient, although the displacement was only 3,750 tons or 1,250 tons less than the fullest of the three vessels. Evidently there is injustice here. No doubt it was not often vessels varied as much as from ·6 to ·8 coefficient nowadays, but how to get back to finer coefficients of displacement was worthy of discussion. Mr. W. T. Courtier-Dutton, speaking at a meeting of this Institution about three years ago, pointed out the difficulties of adopting the load displacement as one of the bases for classification of vessels. It had, however, occurred to him that there would not be the same objection to using the coefficient of displacement along with the plating numerals, *e.g.*, in the tables of Lloyd's register.

The PRESIDENT—Lloyd's tables were not in question.

Mr. ARNISON (resuming)—Well he had prepared a table in which he adopted the numerals of a certain registry as applied to steel vessels.

The PRESIDENT—You must discuss the paper, and not give us one of your own.

Mr. ARNISON (resuming) said he understood the bases of classification was before them; however, he would not attempt to go farther, as he was apparently not in order. In reading the paper the suggestion of employing the coefficient of displacement had occurred to him.

The PRESIDENT—We will be very glad to have a paper from you on the subject.

The PRESIDENT, in adjourning the discussion, said that on the last page of the paper the writer proposed to increase the beam by 10 feet to make the vessel finer. This was increasing the size of the vessel in order to make her finer, and he failed to see how this could be done so as to reduce the cost to the extent anticipated by the writer of the paper. There were points however in the paper which required to be gone into with figures so as to appreciate the correctness of the views put before them. He proposed that they adjourn the discussion till next meeting.

The discussion stood adjourned, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

TENTH SESSION, 1893-94.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, MAY 8TH, 1894.

ROBERT THOMPSON, ESQ., J.P., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, held in Sunderland, on April 11th, 1894, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. John Gravell and Henry Fownes to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Bulmer, John George, Mechanical Engineer, 34, Brighton Grove, Newcastle-on-Tyne.
Lowdon, David, Works Manager, Barry Dry Dock Co., Barry Dock, Cardiff.
Powell, James Richard, Consulting Engineer, Pier Head Chambers, Cardiff.

MEMBERS (LATE GRADUATES).

Clague, James Henry, Ship Draughtsman, Birkenhead Iron Works, Birkenhead.
Oxton, Walter, E. Draughtsman, 96, Blackpool Street, Burton-on-Trent.

GRADUATES.

Bent, John Bradbury, Electrical Engineer Apprentice, 74, Rye Hill, Newcastle-on-Tyne.

Bulmer, Frederick Charles, Mechanical Engineer Apprentice, 1, Graingerville North, Newcastle-on-Tyne.

Bulmer, Septimus, Mechanical Engineer Apprentice, 1, Graingerville North, Newcastle-on-Tyne.

Crawhall, Henry F., Electrical Engineer Apprentice, 58, Westmorland Road, Newcastle-on-Tyne.

Tweddell, G. H., Electrical Engineer Apprentice, 26, Grove Street, Newcastle-on-Tyne.

The discussion on Mr. Arthur Liddell's paper on "Bases for Classification of Vessels Proportioned to their Strength to Resist Bending and Vibration" was resumed and closed.

Closing business of the Session.

ADJOURNED DISCUSSION ON MR. ARTHUR R. LIDDELL'S PAPER ON "BASES FOR CLASSIFICATION OF VESSELS PROPORTIONED TO THEIR STRENGTH TO RESIST BENDING AND VIBRATION.

Mr. A. CRUICKSHANK said it was very unfortunate and much to be regretted that Mr. Liddell should have presented his paper before this Institution in such a crude and unsatisfactory state. This vitally important subject was of a very abstruse character, and required very careful mathematical treatment in all its details. It was only too apparent, after a short perusal of the paper, that Mr. Liddell had treated those details in a very reckless and slipshod manner. The result of this, as might be expected, was that Mr. Liddell had been led into making many fallacious and grossly misleading statements. It would take too long to deal with many of the minor inaccuracies, with which the paper bristled, in fact it would mean rewriting it, but there was one very glaring error to which he specially wished to draw their attention—viz., Mr. Liddell's treatment of what he termed the dynamic or vibration number. In his wave formula of this number he said the length of a rolling wave of the Atlantic was proportional to the square of its speed in knots, and its speed was equal to

$$\sqrt{\text{Length of wave} \times \frac{1}{\cdot 562}}.$$

Now this formula should read, according to Rankine,

$$\sqrt{\left(\frac{L \times g}{2\pi}\right)} \times \frac{1}{1\cdot 688}.$$

Where L = Length of wave

g = Gravity = 32·2 nearly.

And as $\frac{g}{2\pi}$ was constant for all sizes of waves and equal to 5·125, they may write

$$\sqrt{(L \times 5\cdot 125)} \times \frac{1}{1\cdot 688}.$$

And further simplifying they got $\sqrt{(L \times 5\cdot 125)} \times \cdot 592$. Comparing this with Mr. Liddell's formula, and applying it to a 600 feet wave they got the speed equal to

By Mr. Liddell's formula

$$\sqrt{600 \times 1\cdot 78} = 43\cdot 6 \text{ knots.}$$

By correct formula $\sqrt{(600 \times 5\cdot 125)} \times \cdot 592 = 32\cdot 8$ knots. From this

result it would be seen that Mr. Liddell's formula gave 24·7 per cent. excess of vibration due to wave speed alone. He deeply sympathised with Mr. Liddell's object, and was of his opinion that a fine ship ought to have lighter scantlings than a full one. When Mr. Hök was criticising this paper at the last meeting he made a statement which he (Mr. Cruickshank) could not let pass unchallenged. Mr. Hök stated (page 303)—"It was impossible at the present time to calculate the thickness of the plating of a fine ship as compared with a full ship, but they knew so much that if there was any difference at all it was very small." Now he objected strongly to this sentence, and more especially to the latter part, as it was altogether misleading, and not in agreement with some stress calculations to which he would like to refer Mr. Hök. These were made by Mr. A. Denny, and embodied in a paper read by him at the Institution of Naval Architects, in 1892, entitled "Some Notes on the Strength of Steamers." Mr. Denny supposed these steamers to be loaded to their legal draft with sufficient coals to carry them a voyage of 5,000 knots, arriving at their destination when the coal was nearly consumed, they were supposed to meet with waves of their own length, and to be poised upon them. This was about the greatest stress to which they could be subjected, and accounted for the high stresses shown in the following table. Mr. Denny compared seven steamers 350 feet × 44 feet × 32 feet, and took three of them with the same midship coefficient, but an increasing block, and consequently an increasing cylinder coefficient.

	Prismatic Coefficient.	Mid. Coefficient.	Block Coefficient.	Stress per Square Inch Tons.
1	·629	·97	·610	7·93
2	·711	·97	·690	8·50
3	·804	·97	·780	8·95

cent. in the thickness of everything contributing to longitudinal strength of No. 3 ship as compared with No. 1. Or say for every 10 per cent. finer prismatic coefficient a reduction of 6·5 per cent. in the thickness of material contributing to longitudinal strength might be allowed in this size of ship, and still have the same stress per square inch on the hogging girder as the full ship which was taken as the standard. Mr. Denny also gave data for two smaller steamers, which upon analysis present even more striking results in the way of reductions. He (Mr. Cruickshank) trusted that in the near future some member or members of this Institution might be able to invent a satisfactory classification basis for all classes of vessels, which would be accepted by the various registration societies, but he was rather afraid that wishing for the latter part of the sentence was rather like wishing for the millenium.

Mr. Robert H. Muir said he had read the paper through, but not in the sense of having studied it in detail. He would not say much about the points Mr. Cruickshank had raised. He had noted one or two clerical errors, but since entering the room the Secretary had shown him a communication from Mr. Liddell correcting these. Taking this paper as a basis for finding scantlings he was somewhat interested in it, from the fact that he had the honour of being associated with the late Mr. William Denny about the years 1877-78, when he read two papers, one entitled "Lloyd's Numerals," and the other "Lightened Scantlings," before the Institution of Naval Architects. Of course at that time there was considerable difference of opinion on the method of finding a basis for the displacement in the different classification societies. Mr. Denny was willing to accept a formula submitted by the late Mr. William John two years previous in his paper on "The Strength of Steamers," which gave $\frac{D \times L}{35}$. This 35 he decided to use after laborious work in armour-clad vessels whilst engaged at the Admiralty. He found the coefficient for war vessels varied from $\frac{1}{28}$ to $\frac{1}{48}$; but as in that class of vessel they had very heavy weights concentrated in certain parts of the vessel he, after carefully considering the case of merchant vessels loaded with homogeneous cargoes distributed over the vessel's length, thought $\frac{1}{35}$ was a fairly approximate figure to set down as the numeral for strength. When it was suggested to use a displacement basis for fixing the scantlings, various gentlemen objected to it. Even Mr. William John said: "A displacement basis is not a sound mode, and cannot be made a sound mode for determining scantlings. For simplicity sake, and for

various other reasons, they wanted something more definite fixed and simple for a basis on which to determine the scantlings of merchant ships." The year following, discussing the second paper, Mr. Martell said: "All the main objections raised to the former paper still exist, and I could, if I had time, raise an objection to every point, and many more have occurred to me since." Now, it might be interesting to mention one or two of these objections (he need not mention them all), included among others "that it was a fictitious basis." The reply to that was "that a displacement basis, no more than any other empirical basis, can stand comparison with the absolute consideration of scantlings ship by ship." Another objection was "that an owner, having built his vessel to scantlings corresponding to a given draught, might desire to sell or change her trade." Replying to this objection, Mr. Denny said: "The registry societies now lay it down that every vessel be built to do any or every work," so that it was no greater hardship in the one case than the other. The point he (Mr. Muir) would like to bring out was this: Since these papers had been read, the load-line has been fixed by Act of Parliament, thus sweeping away all or most of the objections raised to a displacement basis. He was not aware anything had been written or said further on the matter until now. He thought this paper was a new introduction of the subject and a step forward. He only mentioned these things by way of refreshing his own memory. It was well they should be clear and know where they were starting from in discussing this paper. He thought Mr. Liddell had done a service in re-introducing the subject of a displacement basis, thus opening up the way to the consideration of strength in relation to displacement in a fair and scientific spirit. He did not mean to go into the details, but would

classification societies. They felt their position on the point so strongly that when they had such a problem put before them they at once made up their minds that it was altogether impossible to fulfil the conditions and keep the classification. If they took the Lake steamers of America, or the swift channel or river steamers of their own country, it was altogether out of the question. The actual weight of material necessary for classification alone would absorb all the draught at their disposal. He had had the pleasure of reading a paper during the last week, written by Prof. Byles, at the sister institution in Glasgow. The paper was on the strength of large Atlantic steamers. He treated it very much on the wave principle, as Mr. Cruickshank had spoken of, and he (Mr. Muir) thought, speaking from memory, he took 33 knots as the speed of the large waves. Taking the steamer as going 22 knots against that wave, he found the force likely to be brought on the upper deck or structure above the deck. He took these large steamers both ways: the wave going in the same direction as the steamer, and the time the wave would take to overtake the steamer at the speed, and then the wave coming against the steamer and the time it would take to pass. It was very interesting, and he thought this paper of Mr. Liddell's, taken in connection with that of Prof. Byles's, were valuable additions to their knowledge as naval architects.

Mr. S. O. KENDALL observed that in his paper Mr. Liddell said it was not intended as an attack on existing classification societies, so he assumed from that that one must not consider his remarks too seriously, but as being thrown out in a tentative manner to excite discussion, and perhaps lead to some more tangible result. But there was one point he noticed in his paper, he said "In apportioning material to resist the varying strains to which a ship may be liable, it is not possible to start from first principles of 'given strain to be withstood and factor safety,' as in structures upon land." Well, he understood from this that past experience should be followed, and he thought that was a matter of fact what classifications did do or attempted to do. The rules of most societies of the present day were practically an embodiment of past experience, and had been modified from time to time as experience showed it to be necessary. There was no doubt there would be a slight reduction in the longitudinal strains of a fine vessel, but the question was whether the reduction would be so great as Mr. Liddell assumed it to be, and whether it would run in proportion to the coefficient which he introduced coefficient C. For one

thing he noticed in his diagram he assumed a vessel to be poised at the centre, and with a varying fulness or fineness the bending moment would be proportional to the distance Z Z, that was, supposing the vessel not to be a floating body; but, of course, she was a floating body, and never experienced such extraordinary longitudinal strain when she was afloat. For against the force of gravity acting through Z and Z the floating vessel is subject to an opposite force acting through the centre of buoyancy. These two points differed as the vessel was on the crest in the hollow of the wave. As the positions Y and X, so with the real bending moment, what a vessel was subjected to was not proportional to the distance Z Z, but the distances Z Y and Z X, for it was the same as though they considered the vessel as a beam acting in one direction, and considered the force of the buoyancy as the beam acting in the other direction, as if the centre of buoyancy coincided with Z Z, there would not be any bending moment at all, so that in a fine vessel, although the distance Z Z was contracted, the points Y and X were also contracted to a certain extent, and therefore the real bending moment was not increased or reduced in exact ratio which Mr. Liddell would have them suppose. In fact in a vessel of a certain form, that was to say, with the sections at the ends cut away fine at the keel, as was the practice some fifteen years ago, they might conceive of a case in which a vessel with fine ends when rising on the crest of a wave had actually a higher strain on the gunwale than a vessel with fuller form. He had not had time to go into the formula which Mr. Liddell had produced here, but it certainly seems to be ingenious, and he has exercised a good deal of care in the matter, and he certainly could not agree with the remarks which had been made as to Mr. Liddell's error in the formulæ for the speed of an Atlantic wave, it

thought when tested by actual practice it would be found that the increase of weight in the transverse parts, which he had put down at 15 tons, would be something like twice that or even more. For instance, he increased the breadth of a boat from 36 feet to 46 feet. Well, that in itself would increase the weight of the frames midship at any rate about $\frac{1}{4}$, because he put 10 feet on there, and as he said in the other parts of the rules he would reckon the size of the frame by midship length of them, it would be seen that the frames would have that increase, and a greater increase would be brought about by the beams. He proposed to increase the weight by the beams by the square of the midship beams. If they put 10 feet on the beams, and increased the weight by the square of the length, they would have nearly twice the weight of the beams in the ends, and there were other considerations to be brought in for not increasing beams in that tremendous way. If they increased the beams they would have to increase the pillars, which he did not know had been reckoned on in the calculations. If the increase in beam was such as he proposed in 10 feet on a 36 feet boat, what would it be on 12 feet in a 41 feet boat, and a vessel 310 feet by 41 feet would become 310 feet by 53 feet, and he would not get much saving in the weight of engines driving a vessel of this width, in which case the excessive beam would really counterbalance the advantage gained by the fineness of the ends. And again, as the draught is confined and the displacement lost through fining the ends must be made up by increasing the beam; there was no doubt that vessels designed on such lines would be excessively stiff and very bad sea boats, and that additional transverse strength would be needed to resist the strains produced by heavy rolling. At any rate, he thought as a basis of discussion, if not of ships' scantlings, this paper was of considerable use and advantage to the Institution.

The PRESIDENT intimated that Mr. Liddell being abroad would write his reply, to be added to the *Transactions*. He moved that the best thanks of the meeting be given to him for the paper.

Carried by acclamation.

MR. LIDDELL'S REPLY.

In answering the discussion, the writer wishes first to express his regret for a mistake pointed out by Mr. Hök, viz., the setting of the moment of inertia of the midship section proportional to girth × thickness × depth. For depth must be substituted depth^2, and the correction will appear in the *Transactions*.

The moment to resist bending is proportional to moment of inertia divided by the distance of the neutral axis from the top or bottom of the girder respectively. The latter distance being, in similar sections, proportional to the depth, the moment to resist bending becomes proportional to the sectional area of material × depth, as assumed in the proposed number. The number, as it stands, complies exactly with the conditions of the case of a beam held fast at one end and loaded at the other, the bending moment (displacement × length) being equivalent to weight × lever, and the moments to resist bending (sectional area × depth) being in the two cases the same.

It is the logical outcome of the assumption of a ship at rest alternately on the crest and in the hollow of a wave, and it is a well-known fact, that calculations made on the said assumption give results which are not in accordance with the practice of the registration societies. At the same time it is a fair argument that the rules of the societies have, roughly speaking, stood the test of experience, and it is worth while trying whether the proposed number cannot be made to harmonise with them.

The writer has not had the privilege of reading Prof. Byles's paper, alluded to by Mr. Muir, which would doubtless have thrown light on the subject, and he gives the following under all reserve :—The strains on

length Z X. In the after-body, meanwhile, similar forces have been acting, causing similar strains on the gunwale. The distance X Z, or X Y, is, in similar vessels, proportional to the distance of the still water centre of buoyancy of, say the fore-body, from 'midships, and in dissimilar vessels it is approximately so. Under the usual assumption that the height of the wave is proportional to length, the moment to produce bending then becomes $\propto$ displacement $\times$ L $\times$ coefficient C, as before stated. The action of the forces just described is more or less counteracted by that of another set of forces producing the motions of pitching and dipping. In amount, these are about proportional to the last quantity $\times$ length, or to dimension^5. They are inactive when the ship is about halfway between trough and crest, and they act with increasing effect in throwing the ends upwards as the ship mounts the crest, and downwards as she sinks into the trough. Let the moments due to buoyancy $\times$ leverage be denoted by a, and those due to pitching and dipping by b.

In proportion to the a moments, the b moments, increasing as they do by a higher power of the dimension, will be the greater the larger the vessel, and the resultant moment $(a - b)$ will be relatively greater in the smaller vessels than in the larger ones.

On this account it is probable that with similar waves the moment to produce bending will become more nearly $\propto$ displacement $\times \sqrt{L} \times$ coefficient C.

Here it must be observed that, with a possibly varying draught, it would be more correct to work with the displacement of the horizontal slice of the ship bounded by horizontal planes through the highest and lowest points of the wave. With a given proportion of wave-height to length, the moment to resist bending then becomes $\propto$ displacement of slice $\times \sqrt{L} \times$ a coefficient; or to $L \times B \times L \times \sqrt{L} \times$ a coefficient; or to $\frac{\text{displacement}}{\text{draught}} \times L \times \sqrt{L} \times$ a coefficient.

Now, observation has established the proposition that short waves are on the average higher in proportion than long ones, and if the height of the wave be taken to vary as $\sqrt{L}$ or $\frac{1}{\sqrt{L}}$ L, the corresponding heights would be for a 100 feet wave $= \frac{1}{10}$ L, for a 200 feet wave $= \frac{1}{14 \cdot 1}$ L, for a 400 feet wave $= \frac{1}{20}$ L.

This proportion agrees fairly with that obtaining in the French observed results cited by Mr. W. H. White (*Manual of Naval Archi-*

tecture, page 197), and these being applied to the formula, the moment to resist bending would become $\propto \frac{\text{displacement}}{\text{draught}} \times \sqrt{L} \times \sqrt{L} \times$ a coefficient, or to $\frac{\text{displacement}}{\text{draught}} \times L \times$ a coefficient, and the number would become thickness $\propto \frac{\text{displacement} \times \text{length} \times \text{coefficient } c}{\text{girth} \times \text{draught} \times \text{depth}}$.

The coefficient would, for a given fineness of ends, be equal to $\frac{\text{load water-line coefficient}}{\text{displacement coefficient}} \times$ a coefficient bearing a relation to the coefficient of the load-water line, similar to that borne by coefficient C to the prismatic coefficient in the table given in the paper.

This entails the assignment of new values to coefficient C, somewhat as follows:—

Displacement Coefficient.	Coefficient C.
·4	·600
·5	·535
·6	·500
·7	·482
·8	·478

The values of coefficient C in the new table are about the average ones that would occur in practice.

It will be seen that the effect of fineness of ends, as measured by displacement coefficient × coefficient C, in reducing the bending moment though still present is thus considerably modified, and Mr. Hök's objection on this score is also met.

With regard to the results communicated to the Institution by M. Piaud, and referred to by Mr. Hök, the two vessels compared probably

decrease in the topside plating. In regard to coefficient, a fine-ended ship is practically shorter than a full one of the same absolute length. The mean length, as expressed by length × coefficient of load water-line, though not quite satisfactory would be a fairer standard for the regulation of assumed height of wave, etc., than length itself. Moreover, the dipping motions, which within certain limits appear to be favourable to the strength, are proportionally greater in fine vessels than in full ones.

Referring to the remarks of Mr. Caws, the writer would point out that to obtain the best results as regards speed with a given horse-power, fineness of ends must be associated with suitable lengths of entrance and middle body. It sometimes happens that a full ship with entrance and middle body suited to the speed will give a better result than a finer one, where these lengths are too great or too small. If the wave lengths be properly taken into consideration the sharp-ended vessels always have the advantage.

Mr. Arnison's remarks seem to show that he is in general agreement with the principles embodied in the now corrected number.

The President expressed doubts as to whether a fine ship could be made less expensive than a full one of rather greater displacement and 10 feet less breadth, looking on the former as a larger vessel. The answer to this is that size is not necessarily to be measured by moulded dimensions, and as an illustration it may be remarked that a box 1 foot square, if turned round 45 degs., would measure 1·4 by 1·4 feet over the corners. The gain on the broad ship will be materially modified if the number in its new form be accepted, but a gain may still be expected. The 46 feet ship is an exaggerated case given to illustrate possibilities, and, needless to say, the writer would not advocate such an extreme case in practice.

The writer considers that Mr. A. Cruickshank oversteps the bounds of legitimate criticism and good taste, and that his remarks themselves are more than unfortunate. A more careful mathematical treatment of the quantity $\sqrt{600 \times 1{\cdot}78}$ will show him that it does not give 43·6, but a figure very like the 32·8 obtained by his own elaborate calculation. Probably some of the other minor inaccuracies referred to may be similarly cleared up when more carefully looked into. The writer is pleased to find him endorse the general views underlying the paper, and can cordially re-echo his hope that other members of the Institution may turn their attention to the establishment of a satisfactory classification basis.

In answer to Mr. Muir, the writer wishes to remark that his (the writer's) proposal to apply the vibration number to regulate the scantlings of swift and shallow sea-going steamers was rather a tentative one. Its

employment would have to be preceded by a quantitative investigation into the vertical motions of ships in a sea-way, and into the strains which these are likely to produce. Meanwhile the writer has made a correction in it by striking out breadth from the numerator, and would remark that the correction in coefficient C would eventually apply here as well as in the static number. Probably in applying this number the other set of strains dealt with by the static number would still have an important influence on the scantlings, though less than in ordinary ships.

In answer to Mr. Kendall, the factor of safety for the material of any part of a ship is an unknown quantity. The classification societies know by experience that material of a given thickness applied to a certain part of a given sized ship will not break nor show signs of straining under ordinary conditions of work. The factor may be 3 or 6. All that is known is that the thickness of material is not less than enough. Length × coefficient C (as now altered), while not theoretically exactly correct, is adopted in the proposed number as being a quantity easily obtainable, and at the same time a more correct factor in the measurement of the strains on a ship than the actual length would be.

Mr. Kendall's objection, that the writer has assumed the vessel poised at the centre has already been met by the proposed alteration in the numbers. In regard to the boat increased from 36 feet beam to 46 feet, the increased weight of the transverse parts might exceed 15 tons somewhat, but need not do so to the extent assumed by Mr. Kendall. The beams the writer proposes to regulate each by its own length squared. With certain limitations this would be feasible and reasonable. The end beams would become lighter and the midship ones heavier. The same thing might perhaps be done with the frames and reverse frames, and, as

In conclusion, he wishes to say that he did not approach the subject in any such reckless a manner as that attributed to him by one of the speakers. He consented at the invitation of the Council to put his ideas on bases for classification in the form of a paper, provided he could get some local member to join him in the work. Unable to get help in what proved to be a very large subject, he gave what he could rather than disappoint the Council. While sensible of shortcomings in his work, he still holds his method of treating the problem to be a right one, and the establishment of numbers such as those proposed, modified, it may be, as further investigation may show to be necessary, to be perfectly feasible. He hopes to have helped to advance the subject a step, and to have pointed out roads that may lead to a final solution of the problem.

CLOSING BUSINESS.

Appointment of Auditor.

Mr. John Gravell moved, and Prof. R. L. Weighton seconded, that Mr. R. W. Sisson be reappointed Auditor.—Agreed.

Result of Ballot to fill up Vacancies.

The President said he had now to declare the result of the ballot to fill up vacancies in the Council, the order being alphabetically given :—

President—Alderman Thos. Richardson, B.A., J.P. (Hartlepool).
Vice-Presidents—Mr. J. R. Fothergill, Mr. Hugh Macoll, and Prof. R. L. Weighton, M.A.
Hon. Treasurer—Mr. G. E. Macarthy.
Council—Mr. J. M. Rennoldson, Mr. H. Rowell, Mr. A. G. Schaeffer, Mr. G. W. Sivewright, and Mr. J. E. Stoddart.

The Council had also elected Mr. M. Sandison as Vice-President in place of Mr. J. F. Walliker, who had resigned.

The New President.

The retiring President (Mr. Robert Thompson) said it was his pleasure now to ask Mr. Alderman Thomas Richardson to take the chair for the ensuing year. He was quite sure they would give their new President all the help they had afforded himself. He had great pleasure in asking Mr. Richardson to take the chair.

that the value of this Institution was an increasing one. He felt that in electing him as their President for the coming year they had had a particular desire to confer an honour on a district in which a great many of not the least valuable members resided. He might have had some anxiety in assuming the position; but he felt sure of this, that he should have the valuable assistance not only of those who preceded him in the chair, but also of the Vice-Presidents and members of the Council, and when they looked at the gentlemen who had filled those offices, he thought they would all agree with him there were some amongst them they might reckon as giants in the interests of this Institution. He felt that he could rely upon their cordial assistance and also upon the members generally, and therefore that removed from him a very great anxiety, and it only remained for him to assure them that he should do his best in the interests of the Institution. He had the example of the President who had just vacated the seat, and also those who had gone before him, and he could assure the members that he would take them as his example, and to the best of his ability in no way allow the prestige of this Institution to be lowered. He could only hope it might be his good fortune to see in his time the position and prestige of the Institution greatly increased.

Vote of Thanks to Retiring President.

Mr. F. C. Marshall (Past-President) said the President would pardon him as one of his predecessors if he took the liberty, in the name of his colleagues and of the Council, to congratulate him upon his acceptance of the presidency of that Institution. His duty in rising to speak before him on the first occasion was a very simple one, it was to propose a vote of thanks to his predecessor, Mr. Robert Thompson. The acclamation with which this proposal had been received was a sufficient commendation of Mr. Thompson and the services he had rendered to the Institution during the last two years. He had been most assiduous in his duties, and had served the office of President in a very valuable and very interesting way. They had frequently had opportunities of meeting, and there was nothing Mr. Thompson could have done to advance the interests of the Institution that he had not done. He only expressed the feelings of the Council and members in moving a very hearty vote of thanks to Mr. Thompson for his services in the chair.

Mr. Wm. Boyd (Past-President) seconded the motion. He could only regret that he had not been able to form an estimate of Mr.

Robert Thompson's services to this Institution by that attendance at the General Meetings which, perhaps, might have been thought necessary to form an adequate opinion; but he had attended a good many Council meetings, and he wished to remind them that the work of the President of the Institution was by no means limited to taking the chair at such meetings as this. There was a very great deal of work went on "behind the scenes," which did not appear to the outside public or ordinary members of the Institution, but which was none the less necessary and valuable for the progress of such an Institution as this. It appeared to him that although the Institution had no doubt attained a very great measure of success, its opportunities for usefulness and the place it had to occupy, and could occupy, in the scientific world in future, was none the less important, and, in fact, was of growing importance. They saw around them on all sides tendencies by which the energies of those who busied themselves with engineering and other industrial pursuits, had their efforts contracted by "labour" doing as little as it possibly could. Not as much as it possibly could, but as little as it possibly could, and if the manufacturing districts of the country were to hold their own they must rely upon labour-saving appliances, they must rely upon means for developing mechanical appliances for taking the place of mere manual operations, and in the devising of such appliances, and in perfecting such means as would take the place of ordinary unskilled labour, there was an enormous field open to the members of this Institution. He cordially recommended that field to their attention, and he could assure them that those who were interested in the industrial production of this country would welcome with open hands any advantages or any appliances that they might bring before their notice. No

had been a pleasure to him to look after the interests of the Institution. He had tried all through, in every way he could, to uphold the prestige of the Institution, and, where possible, to enlarge it. He also felt that the assistance of the Past-Presidents, Vice-Presidents, and Councilmen had always been readily given, and he had always tried at their meetings to gauge their opinion so that the Institution would be carried on as by the Council through the President. He was very glad his course of action met with their approval, for it enabled him to feel that night that he had done his duty, and that it had been performed agreeably to their feelings. He was sure the President would get valuable assistance from the Past-Presidents, Vice-Presidents, Councilmen, and last, but not least, from their Secretary (Mr. Duckitt). He was most indefatigable in his work, and if the President was a little behind, he would undertake to say the Secretary would keep pulling him on. It had been his experience, and he had benefited by it. He was sure the Institution would progress. He was glad Mr. Boyd had referred to mechanical appliances for the saving of labour, and thought they might have papers on the subject, especially considering the way trades unionism and labour questions were turning. He thought they might have a very good paper on the subject (and he trusted some members of the Institution would take the hint) which might be scientifically discussed both from the shipbuilders' and engineers' point of view. He had to thank Mr. Marshall, Mr. Boyd, and the gentlemen present for the hearty way in which they had carried this vote.

Vote of Thanks to the Retiring Vice-Presidents and Councilmen.

Mr. Robert H. Muir said he had been asked to propose the thanks of the Institution to the retiring Vice-Presidents and Councilmen. As Mr. Thompson had assured them they had always been ready to give him assistance wherever necessary. It was always necessary to have a head to any association, but the head alone could not do everything, and the Vice-Presidents and Councillors had worked very assiduously, he was sure, in assisting Mr. Thompson during his two years of office. He was a comparative stranger, but perhaps on that account could take a more independent view of their position, and he could say that the attention given to their meetings and the quality of the papers were most commendable. He hoped that the newly-elected Vice-Presidents and Councilmen would be no less helpful and useful than those to whom he now moved their best thanks.

with steam cylinders 2 feet 11 inches diameter, and blowing cylinders 6 feet 7 inches diameter, and 8 feet stroke; and the fourth pair with steam cylinders 3 feet 1 inch diameter, and blowing cylinders 7 feet 6 inches diameter, and 7 feet 11 inches stroke.

At present six furnaces are in blast, producing Bessemer pig-iron, of which the average yield per furnace is about 750 tons weekly, but as much as 919 tons in a week have been obtained from one furnace.

The largest proportion of the iron ore used is procured from the Company's mines near Bilbao, in Spain, but quantities of other high class mineral are also used in conjunction therewith.

The waste gases are utilised for heating the stoves and in raising steam for driving the blast engines. There are altogether some 31 boilers in connection with the blast-furnaces, 19 of them egg-ended, and 12 double tubular.

When iron plates were exclusively used for shipbuilding purposes the plant of the Company was almost entirely devoted to the manufacture of plates of this material, and for this purpose they had 170 puddling furnaces and seven plate mills, and turned out about 1,900 tons of iron ship plates weekly, but with the large substitution of steel for iron some portions of this plant have become obsolete, whilst others have been modified for the purpose of producing steel, and at the present time there are only 40 puddling furnaces and two plate mills for the production of iron plates. These latter are at the old "Tinmill" works, at which place also iron chequered plates are rolled.

The Company commenced the manufacture of Siemens steel in the year 1883, in a small way at first, gradually extending their operations until they have now become one of the largest makers of the kind in this

VISIT TO THE CONSETT IRONWORKS.

In response to the kind invitation received by the Council from Messrs. The Consett Iron Co., Limited, a visit was paid to the above works on Thursday, July 19th.

About 250 of the members availed themselves of the opportunity granted, and a special train, which left Newcastle at 11·45 a.m., was provided to convey them to Consett. On arrival at the works the party was divided into three companies, and under the guidance of Mr. George Ainsworth (general works manager), Mr. Hy. Holliday (secretary and commercial manager), and the other officials, the whole of the various processes of manufacture were inspected and explained.

The works of this Company were originally established in 1840. They are situate at Consett, about midway between Newcastle and Durham, on the Derwent Valley branch of the North Eastern Railway. (See Plate XXX.).

The staple trade is iron and steel plates, and steel angles, bars, etc., besides which the Company are large coal-owners and manufacturers of coke, both for consumption at their own blast-furnaces and for sale.

The present capacity for weekly output is as follows :—

Iron plates	500 tons.
Steel plates	2,500 „
Steel angles, etc.	1,500 „
	4,500 tons.

The Company's coal-field covers an area of 13,000 acres, and at the present time ten collieries are in operation, seven of them in the neighbourhood of the works, two at Langley Park, near Durham, and one at Garesfield.

The annual quantity of coal raised is about 1,000,000 tons, which it is expected will be considerably increased when the more recently acquired properties on the north side of the river Derwent have been opened out.

There are upwards of 1,000 coke ovens in operation, the annual output being about 500,000 tons.

The Company's blast-furnace plant consists of seven furnaces 55 feet high by 20 feet diameter of bosh, equipped with Cowper's and Whitwell's fire-brick stoves for heating the blast, which enters the furnaces at a temperature of about 1,300 degs. Fah.

There are four pairs of beam engines for raising the blast for the furnaces; two pairs with steam cylinders 4 feet 2 inches diameter, and blowing cylinders 8 feet 4 inches diameter, and 9 feet stroke; one pair

carrying the plates in process of manufacture from the roughing to the finishing rolls. The average weekly production of finished steel plates in this mill alone is about 1,100 tons.

The angle mills, which are of recent construction, are contiguous to the north melting shop already alluded to, and cover an area of about 16 acres. They are provided with the most modern plant and machinery, consisting of a 45 inches cogging mill, with bloom cutting shear, and a 32 inches, a 22 inches, and a 12 inches guide mill, all with their necessary engines, live roller gear, billet skids, heating furnaces, boilers, hydraulic plant, overhead cranes, hotsaws, billet and scrap cutting shears, bar banks, and bar skids, together with the other needful accessories, the whole being designed for a production of 1,500 tons sectional steel of every description, such as angles, tees, bulbs, channels, girders, round and square bars, etc.

The Company have also large engineering shops, foundry, locomotive and wagon repairing shops, and well equipped laboratory, in connection with the works. At their brickworks 120,000 bricks are turned out per week.

They own about 2,700 cottages at Consett, Blackhill, Leadgate, and the outlying districts, and employ upwards of 6,000 hands, the wages at present paid amounting to £8,000 per week, or £416,000 per annum. Besides having miles of railway of their own, they contribute to the North Eastern Railway Company in dues, the large sum of £150,000 annually.

The tour of the works having been completed, the members were conveyed to the Consett Town Hall, where a sumptuous luncheon was provided by the Company, presided over by the Chairman (David Dale, Esq.).

must tend to failure. The works were established in 1840 by a private partnership under the name of the Derwent Iron Company, which was formed for the purpose of working the local coal and the ironstone associated therewith, and converting the latter into pig iron and the pig iron into rails. The partnership, however, unfortunately did not include anyone who had experience in the kind of business to be carried on, and it possessed what persons were too readily in the habit of regarding as an unqualified advantage, a very liberal banker. Inexperienced and with unlimited banking accommodation the works were so erected, so extended, and so conducted as that they came to owe their accommodating banker nearly a million of money, and on the Northumberland and Durham District Banking Company, who had afforded this accommodation, stopping payment in November, 1857, the Derwent Iron Company had to suspend payment also. The works then passed under the control of a committee of creditors, of whom he (the Chairman) was one, and it was in this manner that his connection with Consett was established about thirty-six years ago. An attempt was made by a combination of the shareholders of the bank, under the headship of the late Mr. Christian Allhusen, to acquire the works, and they were for a few years carried on under the name of the Derwent and Consett Iron Company by that combination, but still under creditor supervision. Ultimately, in 1864, just thirty years ago, the present Consett Iron Company was formed, with the late Mr. Henry Fenwick and Mr. John Henderson as chairman and vice-chairman, and with the late Mr. Jonathan Priestman and himself (Mr. Dale) as joint managing directors. On Mr. Priestman's retirement in 1869 the directors were fortunate to secure the services of Mr. William Jenkins as general manager, and to that gentleman's great experience, gained at the Dowlais ironworks in South Wales, to his ability and untiring devotion to the company's interests, the success of the past twenty-five years and the present position of the company is largely due. Almost concurrently with the engagement of Mr. Jenkins there came into the company's service Mr. Richard Evans as secretary and commercial manager, and the company had sustained an irreparable loss in the death of that gentleman a few months ago. Those who knew Mr. Evans would best realise how great that loss was. He (the Chairman) had that day to introduce to them Mr. Evans's successor, Mr. Henry Holliday, a gentleman not altogether unknown, he felt sure, to many present. It was, he knew, a matter of regret to them all that Mr. Jenkins's health had seriously failed, and that he was now obliged to abstain entirely from

attention to business. Under these circumstances Mr. Ainsworth, who had also been about a quarter of a century in the services of the company, had had placed upon him the responsibilities of general works manager, and he did not doubt that if Mr. Jenkins proved unable or thought it imprudent to resume managing responsibilities these two gentlemen, Mr. Ainsworth and Mr. Holliday, would unitedly sustain the prestige of the Consett Iron Company, and secure for it in the future the reputation and success which it had earned in the past. He trusted that the visit paid to the works that day had been one of interest and pleasure, and he again accorded to the guests of the day a hearty welcome.

Mr. Alderman Thos. Richardson (President of the Institution), in acknowledging the handsome way in which they had been treated by the company and its officials, expressed the pleasure it gave him in proposing "Continued success to the Consett Iron Company." In this he was ably supported by Mr. Robert Thompson (the immediate Past-President.) Mr. Thomas Bainbridge having responded on behalf of the directors of the company, and Mr. Ainsworth and Mr Holliday on behalf of the officials, the whole party, after having spent a pleasant and instructive visit, repaired to Consett railway station for the return journey to Newcastle.

APPENDIX.

CATALOGUE OF BOOKS, TRANSACTIONS, AND PERIODICALS IN LIBRARY, JULY, 1894.

(1.) Transactions of Learned Societies.

American Society of Mechanical Engineers, New York City, N.Y., Vol. I. to date.
American Society of Naval Engineers, Navy Department, Washington, U.S. of America, Vol. I. to date.
Canadian Society of Civil Engineers, Montreal, Canada, Vol. I. to date.
Civil and Mechanical Engineers, 1888-89.
Cleveland Institution of Engineers, Middlesbrough, 1889 to date.
Engineering Association, Sydney, New South Wales, Australia, Vol. I. to date.
Engineers and Shipbuilders in Scotland, Glasgow, Vol. III. to date.
Genio Civile, Roma, Vol. XXII. to date.
Hull and District Institution of Engineers and Naval Architects, Hull, Vol. I. to date.
Institution of Civil Engineers, London, Vols. XVII., XXI., XXVI. to XXXIV. (inclusive), L., LIII., LIV., and LXXIX. to date.
Institution of Civil Engineers, London, 7 Volumes Pamphlets, 1837, 1852.
Iron and Steel Institute, London, 1885 to date.
Junior Engineering Society, London, 1884 to date.
L'Association Technique Maritime, Paris, Vol. I. to date.
Liverpool Engineering Society, Liverpool, Vol. I. to date.
Liverpool Polytechnic Society, Liverpool, 1865, 1866, 1867, 1868, 1873, and 1887 to date.
Manchester Association of Engineers, Manchester, 1883 to date.
Marine Engineers, Institute of, Vol. I. to date.
Mechanical Engineers, London, 1885 to date.
Midland Institute of Mining, Civil, and Mechanical Engineers, Barnsley, 1884 to date.
Naval Architects' Institution, London, Vol. I. to date.
North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, Vol. XXXIV. to date.
North-East Coast Institution of Engineers and Shipbuilders, Vol. I. to date.
Philosophical Society, Glasgow, Vol. XIX. to date.
Royal Dublin Society, Dublin, *Transactions*, Vol. III. to date; *Proceedings*, Vol. IV. to date.
Society of Arts, London, Vol. XXXVII. to date.
Society of Engineers, London, 1884 to date.
Société des Ingénieurs, etc., de Liége, *Bulletin*, 1885 to date; *Annuaires*, 1885 to date.
Société Scientifique de Marseille, Vol. I. to date.
South Wales Institute of Engineers, Cardiff, 1884 to date.
United States Naval Institute, Annapolis, Maryland, U.S. of America, 1886 to date.

(2.) Technical Journals and Periodicals.

Electrical Engineer, London, Vol. III. to date.
Electrical Review, London, Vol. XXIV. to date.
Engineering, London, Vols. IV., V., and VI., XX. and XXI., XXV. to XXXII., and XXXIV. to date.

Indian Engineer, Calcutta, British India, Vol. VII. to date.
Indian Engineering, Calcutta, British India, Vol. III. to date.
Industries, London, Vol. I. to 1893.
Industries and Iron, London, 1893 to date.
Iron, London, 1888 to 1893.
Iron and Coal Trades Review, London, Vols. XXXVI. and XXXVII. only.
Journal de La Marine le Yacht, 1892 to date.
Marine Engineer, London, Vol. VII. to date.
Mechanical World, Manchester, 1886 and 1889 to date.
Revista Marittima, Rome, Vol. I. to date.
Shipping World, London, Vol. IV. to date.
Stahl und Eisen, Düsseldorf, Vol. IX. to date.
The Electrician, London, Vol. XXXI. to date.
The Engineer, London, Vol. LIX. to date.
The Mechanics' Magazine, 1864-1866 (3 vols.).
The Practical Engineer, Manchester, Vol. I. to date.
The Practical Mechanics' Journal, London, 1863 to 1870 (4 vols.).
The Steamship, London, Vols. I. and II.
The Steamship, Leith, Vol. I. to date.
Transport, London, Vol. II. to date.

(3.) General.

(a.) *Engineering and Mechanical.*

Applied Mechanics	Prof. Rankine	1888
Do.	J. H. Cotterill	1890
Boilers and Boiler Making	N. P. Burgh	1873
Boilers, their Construction and Strength...	T. W. Traill	1888
Bridge Construction	T. C. Fidler	1887
Bureau of Steam Engineering (U.S.A.), Report of		1889-90
Bureau Veritas—Report on Steel		1878
Chemical Analysis of Iron	Blair	1891
Civil Engineering	Prof. Rankine	1889
Elements of Machine Design (2 vols.)	Unwin	1891

Iron and Steel Industries, Report on, in Foreign Countries ...		
Iron Roofs	A. T. Walmsley	1888
Machinery and Millwork	Prof. Rankine	1887
Manual of Machine Drawing and Design ...	D. A. Low & A. W. Bevis	1893
Manual of Marine Engineering	A. E. Seaton	1889
Manufacture of Iron and Steel, Principles of	I. L. Bell	1884
Marine Boiler Management and Construction	C. E. Stromeyer	
Marine Engineering (2 vols.)	W. H. Maw	
Marine Propellers (3 copies)	S. W. Barnaby	1891
Marine Steam Engine	R. Sennett	1885
Materials of Engineering (3 vols.)...	R. H. Thurston	1884
Mechanician, The	Knight	1888
Mechanical Graphics	G. Halliday	1889
Mechanical Text Book	Prof. Rankine	1884
Mechanical Engineers' Reference Book	N. Foley	1891
Mechanics of Machinery	Kennedy	1886
Metallurgy of Iron, Treatise on	H. Bauerman, F.G.S.	1890
Metallurgy of Steel	H. M. Howe	1890
Metallurgy	Phillips & Bauerman	1891
Metals: Their Properties and Treatment...	C. L. Bloxham	1885
Mill Gearing, etc.	T. Box	1888
Modern French Artillery	Dredge	1892
Modern Marine Engineering (2 vols.)	N. P. Burgh	1872
Papers Read before the International Engineering Congress (1 set, 2 vols., Marine Engineering and Naval Architecture, 1 set, 2 vols., Civil Engineering)		1893
Pocket Book on Boilers	T. W. Traill	1888
Practical Magazine		
Report of Boiler Committee		1893
Rules and Tables	Prof. Rankine	1889
Rules, Tables, and Data for Mechanical Engineers	D. K. Clark	1890
Screw Propeller	W. Bourne	1867
Slide Valve	N. P. Burgh	1868
Steam and the Steam Engine, Text Book on	A. Jamieson	1889
Steam Engine	G. C. V. Holmes	1890
Do. (4 vols.)	D. K. Clark	1890
Do.	J. H. Cotterill	1890
Steam Boilers	R. Wilson	1879
Do.	R. H. Thurston	1888
Steam Engine	Prof. Rankine	1888
Steam Engine and the Indicator	Le Van	1890
Strains in Structures	G. A. T. Middleton	1889
Strength of Materials	T. Box	1888
Do. do.	Unwin	1888
Strength of Iron Parts of Steam Machinery	Van Buren	1869
Strength of Beams and Columns	Cousin	1889
Structures, Design of	Anglin	1891
Substitution of Metal for Wood in Railway Ties, Report on ...	B. E. Fernon	1890
Testing Materials of Construction	W. C. Unwin	1888
Theory of Stresses	B. B. Stoney	1886
Turbine, The	W. Cullen	1871
Valve Gears	J. F. Klein	1884
Wire, Its Manufacture and Uses	J. B. Smith	1891

(b.) *Shipbuilding, etc.*

Annals of Lloyd's Register		1884
British Corporation for the Survey and Registry of Shipping ...	Glasgow	1893
Bureau Veritas Register of Shipping		1887 to date
German Lloyd's International Register of Shipping		1891 to date
German Lloyd's Rules and Regulations		1891 „
Illustrated Marine Encyclopedia	H. Paasch	1890
Keel to Truck	„	1885
Lloyd's Register of British and Foreign Shipping (2 vols.) ...		1891 to date
Lloyd's Rules and Regulations		1891 „
Modern Shipbuilding and the Men Engaged in it	D. Pollock	1884
Naval Architecture, Manual of	W. H. White	1889
Do. do.	„	1894
Naval Annuals ... ... Lord Brassey		1886, 1887, 1890 to date
Naval Science (4 vols)	E. J. Reed	1872-5
Report of the Committee on the Spacing and Construction of Watertight Bulkheads		1891
Resistance of Ships and Screw Propulsion	D. W. Taylor	1893
Shipbuilding, Theoretical and Practical	Prof. Rankine	1866
Shipbuilding (2 vols.)	Thearl	1886
Shipping World Year Book		1887
Stability of Ships	Sir E. J. Reed	1885
Do.	J. C. Spence	1884
Steam Navigation	B. Woodcroft	1848
Yacht and Boat Sailing	D. Kemp	1891
Yacht Architecture	„	1891

(c.) *Electrical.*

Dynamos, Alternators, and Transformers...	Kapp	1893
Dynometers and the Measurement of Power	Flather	1892
Dynamo Electric Machinery	Thompson	1892
Dynamo Electric Machines...	Hering	1890
Electro Magnet	Thompson	1891
Electricity and Magnetism (2 vols.)	J. C. Maxwell	1881
Elementary Treatise on do.		1881

Duties of Executors...	F. W. Dendy	1889
Elements of Projective Geometry...	Cremona	1885
Foreign Office List ...		1886
Geology of England and Wales ...	H. B. Woodward	1887
Handbook to Industries, N. E. District of England ...	W. Richardson	1889
Imperial Journal (3 vols.) ...		
Industrial Resources of the Tyne, Wear, and Tees...	Lord Armstrong and others	1864
Light...	L. Wright	1882
Management of an English Railway ...	G. Findlay	1891
Marine Transport of Petroleum ...	Little	1890
Miscellaneous Scientific Papers ...	Prof. Rankine	1881
Practical Treatise on Petroleum ...	B. J. Crew	1887
Record of the International Exhibition, London...		1862
River Tyne, History and Resources of ...	J. Guthrie	1880
Royal Atlas of Modern Geography ...	T. B. Johnston	1894
Service Chemistry ...	V. B. Lewes	1889
The Spectator ...		
Water-Gas Plant, a description of...	S. Fox	1888
Water Ways and Water Transport ...	Jeans	1890
Year Book of Scientific Societies ...		1890 to date

(*e.*) *Biographical.*

Lives of Brindley and others ...	Smiles	1874
„ Boulton and Watt ...	„	1878
„ William Denny ...	A. B. Bruce	1889
„ Metcalf and Telford ...	Smiles	1874
„ James Nasmyth ...	„	1885
„ Smeaton and Rennie ...	„	1874
„ G. and R. Stephenson ...	„	1879
„ R. Trevethick ...	F. Trevethick	1872
Diaries of Sir Daniel Gooch, Bart. ...		1892

(*f.*) *Dictionaries.*

Annandale's Concise English Dictionary...		1891
Dictionary of Engineering (4 vols.) (2 sets) ...	Spon	1874
Dictionary of Terms relating to Iron ...	A. Tolhausen	1870
French and English Dictionary (2 vols.) ...	L. Smith & H. Hamilton	1882
German and English Dictionary ...	Theime-Preusser, E. Wesseley	
Italian and English Dictionary (2 vols.) ...	Millhouse	
Spanish and English Dictionary ...	Bustamantes	1890
Technological Dictionary (3 vols.)...	A. Tolhausen	1883

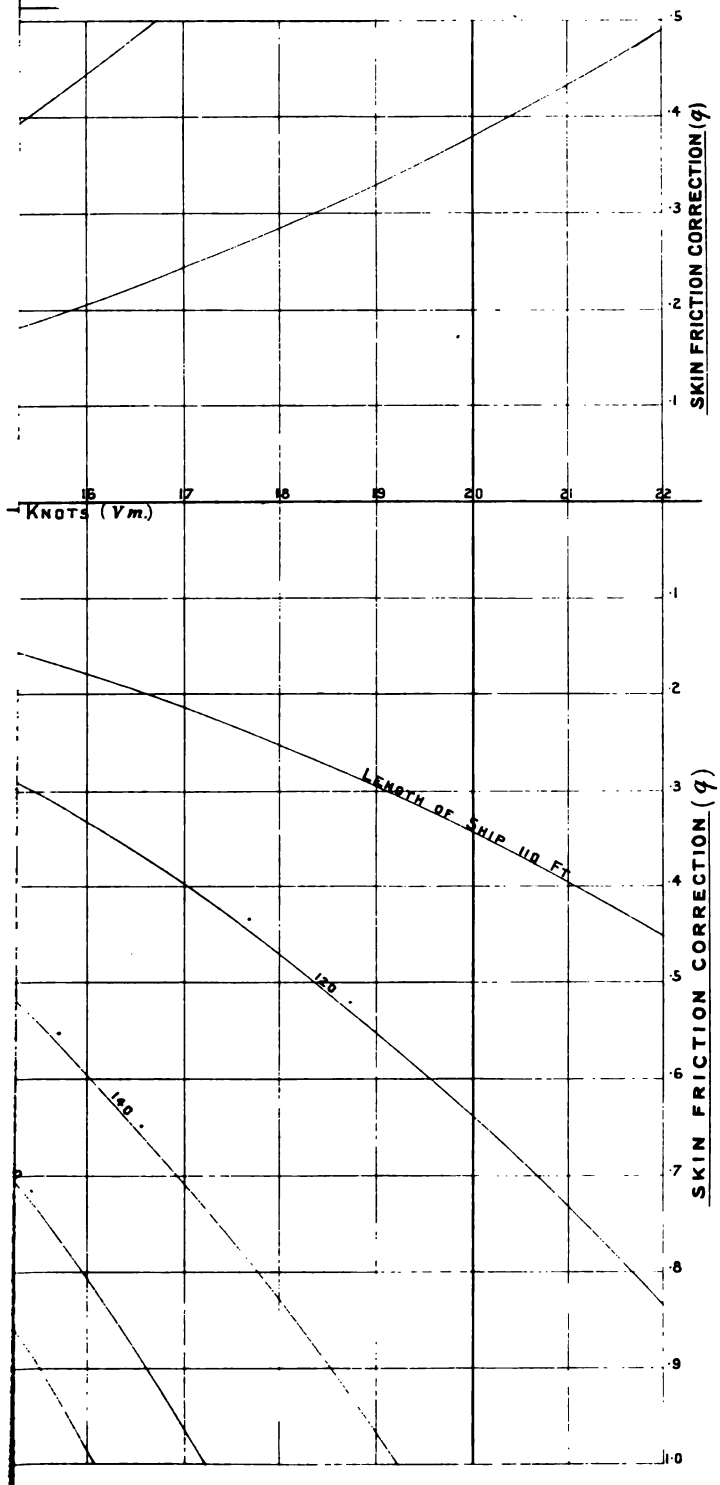
Sundry Business Directories.

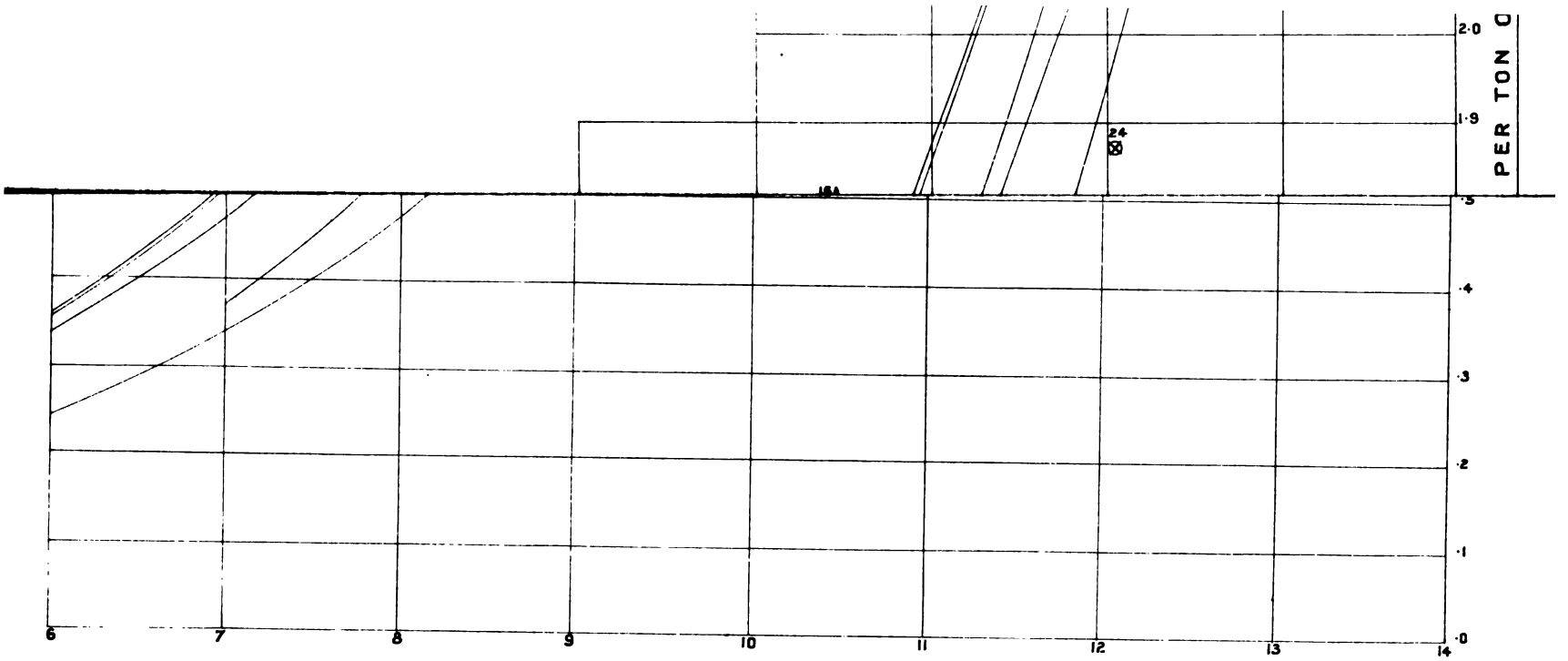
Copies of Transactions are received from the following Societies:—

American Society of Civil Engineers, 127, East Twenty-third Street, New York, U.S.A.
American Soc. of Mechanical Engineers, 12, West 31 Street, New York City, N.Y.
American Society of Naval Engineers, Navy Department, Washington, U.S. of America.
Bureau of Steam Engineering, Navy Department, Washington, U.S. of America.
Bureau Veritas, 8, Place de la Bourse, Paris.
Canadian Society of Civil Engineers, 112, Mansfield Street, Montreal, Canada.
Cleveland Institution of Engineers, Middlesborough.
Engineering Association, 34, Jamieson Street, Sydney, New South Wales, Australia.
Engineers and Shipbuilders in Scotland, 207, Bath Street, Glasgow.
Genio Civile, Alla Direzione della Bibliotica, e dell' Archivio tecnico, del Ministero *dei Lavori Pubblici*, Roma.
Germanischer Lloyd, 52, Markgrafen Str., Berlin, W.
Hull and District Institution of Engineers and Naval Architects, 118, Londesborough Street, Hull.
Institution of Civil Engineers, 25, Great George Street, Westminster, London, S.W.
Iron and Steel Institute, Victoria Mansions, Victoria Street, London, S.W.
Junior Engineering Society, 47, Fentiman Road, London, S.W.
L'Association Technique Maritime, 8, Place de la Bourse, Paris.
Liverpool Engineering Society, Royal Institution, Colquit Street, Liverpool.
Liverpool Polytechnic Society, Royal Institution, Colquit Street, Liverpool.
Lloyd's Register of British and Foreign Shipping, 2, White Lion Court, Cornhill, London.
Manchester Association of Engineers, 63, Barrett Street, Old Trafford, Manchester.
Marine Engineers' Institute, 58, Romford Road, Stratford, Essex.
Marine Engineers' Union, Newcastle-upon-Tyne.
Marine Engineers' Union, South Shields.
Mechanical Engineers, 10, Victoria Chambers, Westminster, London, S.W.
Midland Institute of Mining, Civil and Mechanical Engineers, Eldon Street, Barnsley.
Naval Architects' Institution, 5, Adelphi Terrace, London.
North of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle-upon-Tyne.
Philosophical Society, 207, Bath Street, Glasgow.
Royal Dublin Society, Kildare Street, Dublin.
Society of Arts, John Street, Adelphi, London, W.C.
Society of Engineers, 6, Westminster Chambers, Victoria Street, London, S.W.
Société des Ingénieurs, &c., de Liége—Boulevard Savey, 20, Liége.
Société Scientifique Industrielle de Marseille, 61, Rue Paradis, Marseilles.
South Wales Institution of Engineers—Hort Huxham, Esq., Park Place, Cardiff.
United States Naval Institution, Annapolis, Maryland, U.S. of America.

The Institution is also placed on the Free List of the following Publications, copies of which lie on the Tables in the Reading Room:—

Electrical Engineer, 139, Salisbury Court, Fleet Street, London, E.C.
Electrical Review, 22, Paternoster Row, London, E.C.
Engineering, 35 and 36, Bedford Street, Strand, London, W.C.
Engineers' Gazette, Prudential Buildings, Newcastle-upon-Tyne.
Indian Engineer, 4, Dalhousie Square, Calcutta, British India.
Indian Engineering, Pat. Doyle, Esq., C.E., Star Press, 19, Lall Bazar, Calcutta, British India.


SKIN FRICTION CORRECTION (q)
·1
·2
·3
·4
·5
15
17
18
19
20
21
22
KNOTS (Vm.)
SKIN FRICTION CORRECTION (q)
·1
·2
·3
·4
·5
·6
·7
·8
·9
1·0
LENGTH OF SHIP 110 FT.
120.
140.



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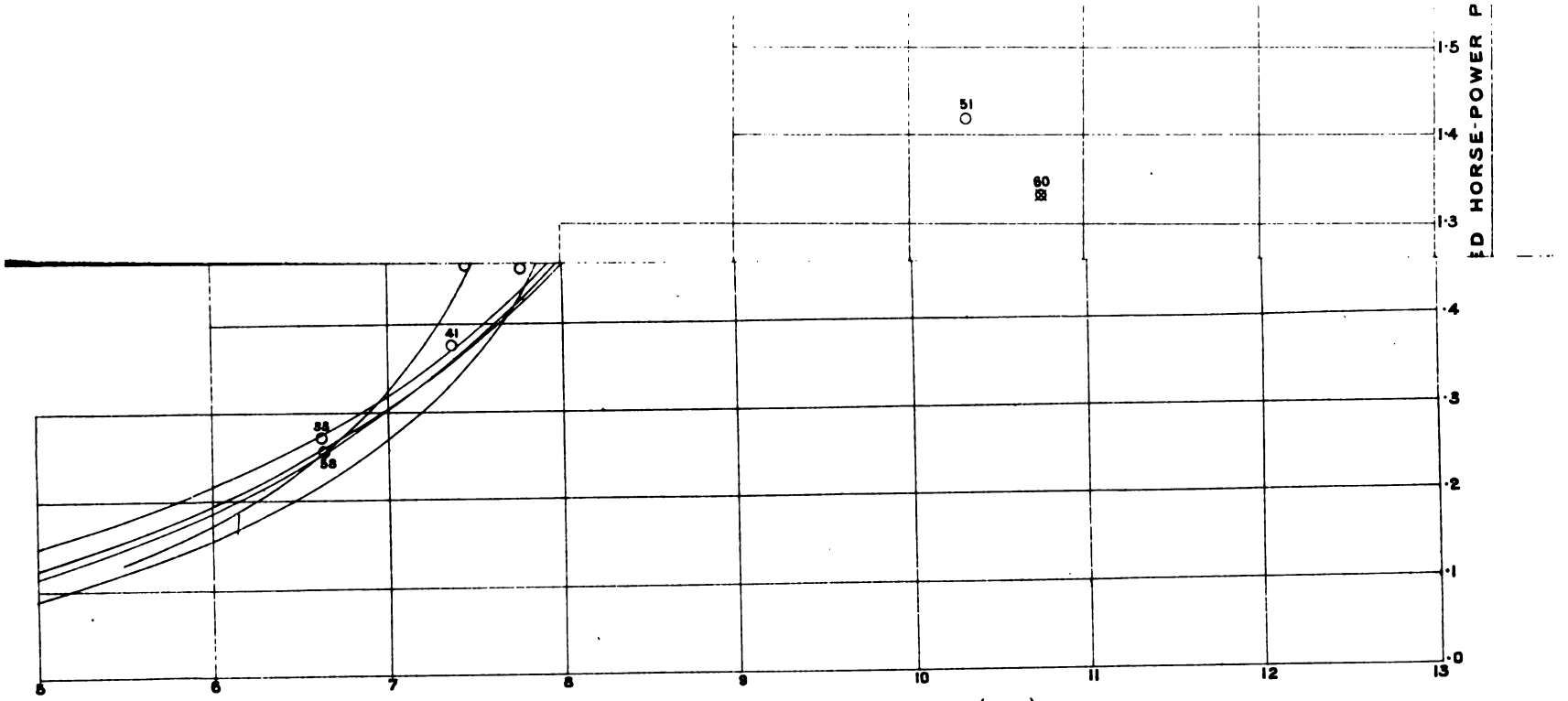
51
60
41
38
58
1·5
1·4
1·3
·4
·3
·2
·1
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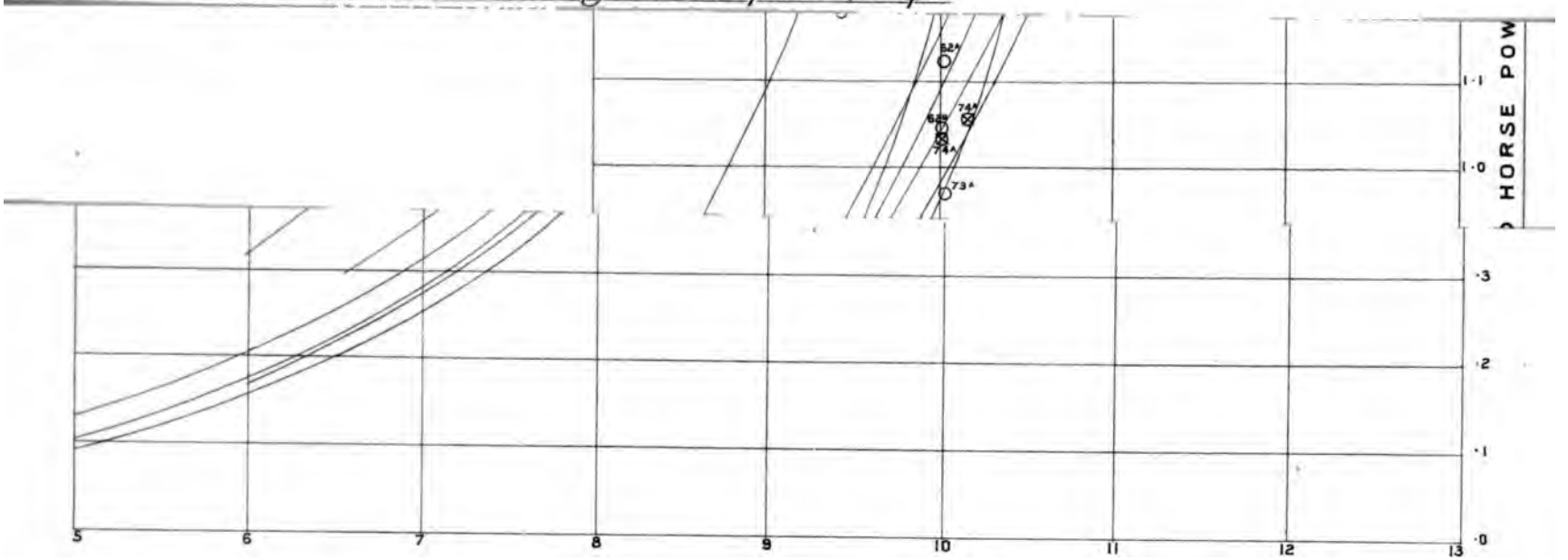
5
6
7
8
9
10
11
12
13
SPEED OF 100 FT MODEL IN KNOTS (Vm)

To illustrate Mr. W. Hok's Paper on "A Method of Comparing Steamship Performances and of Estimating Powers & Speeds of Ships."



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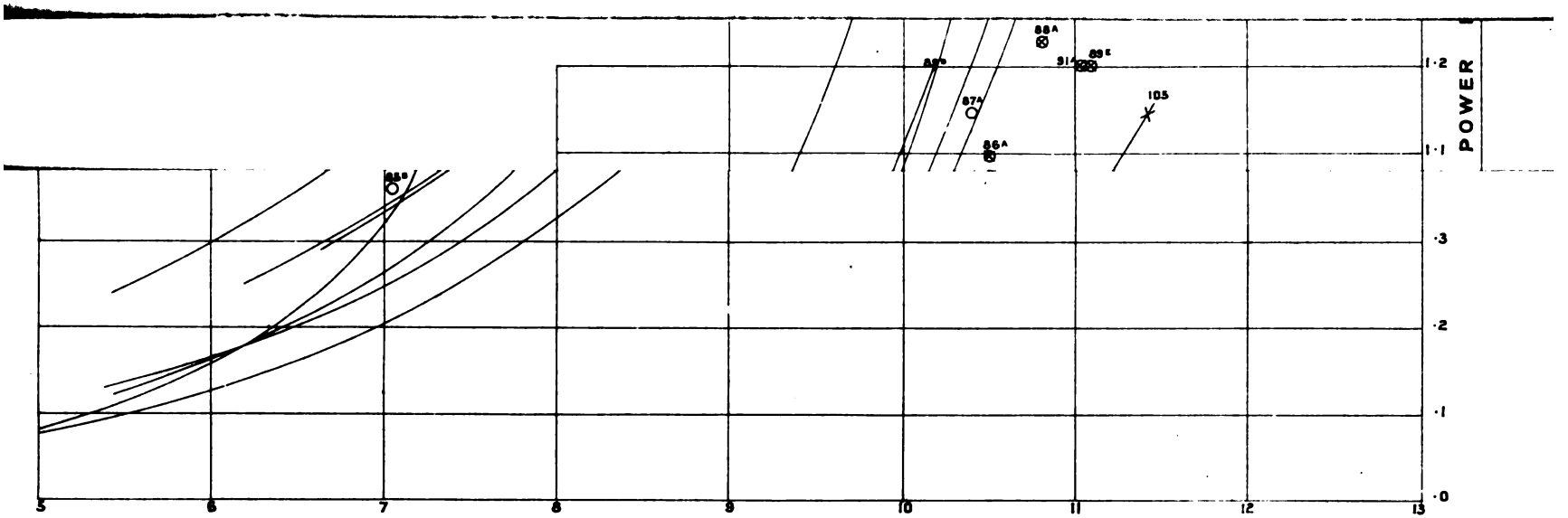

SPEED OF 100 FT MODEL IN KNOTS (V_m.)

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Session X.

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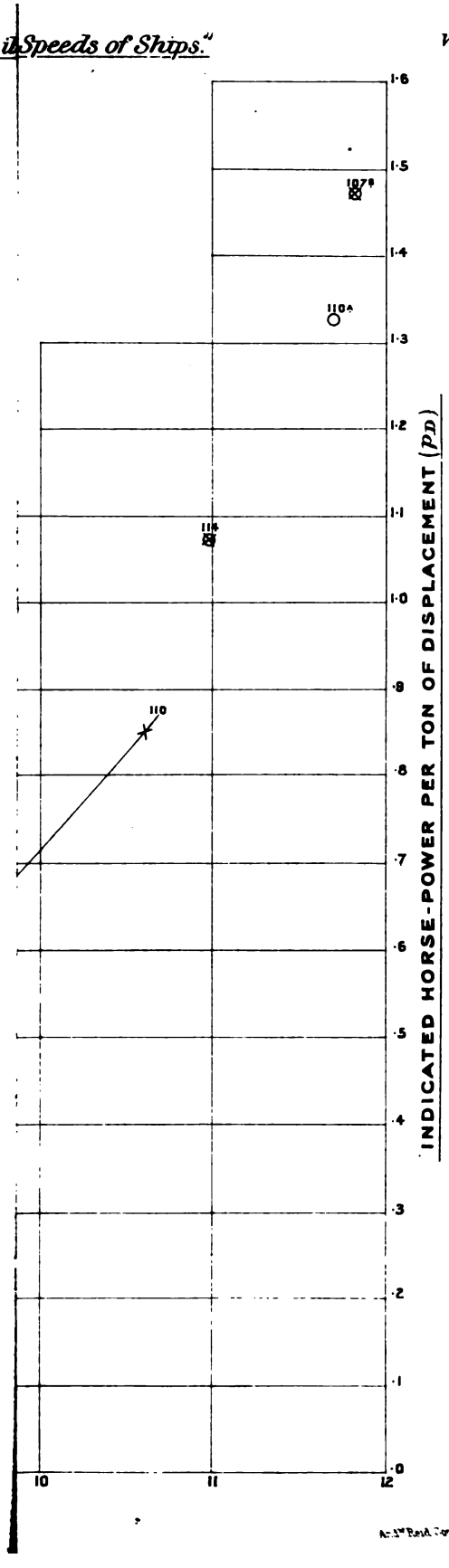

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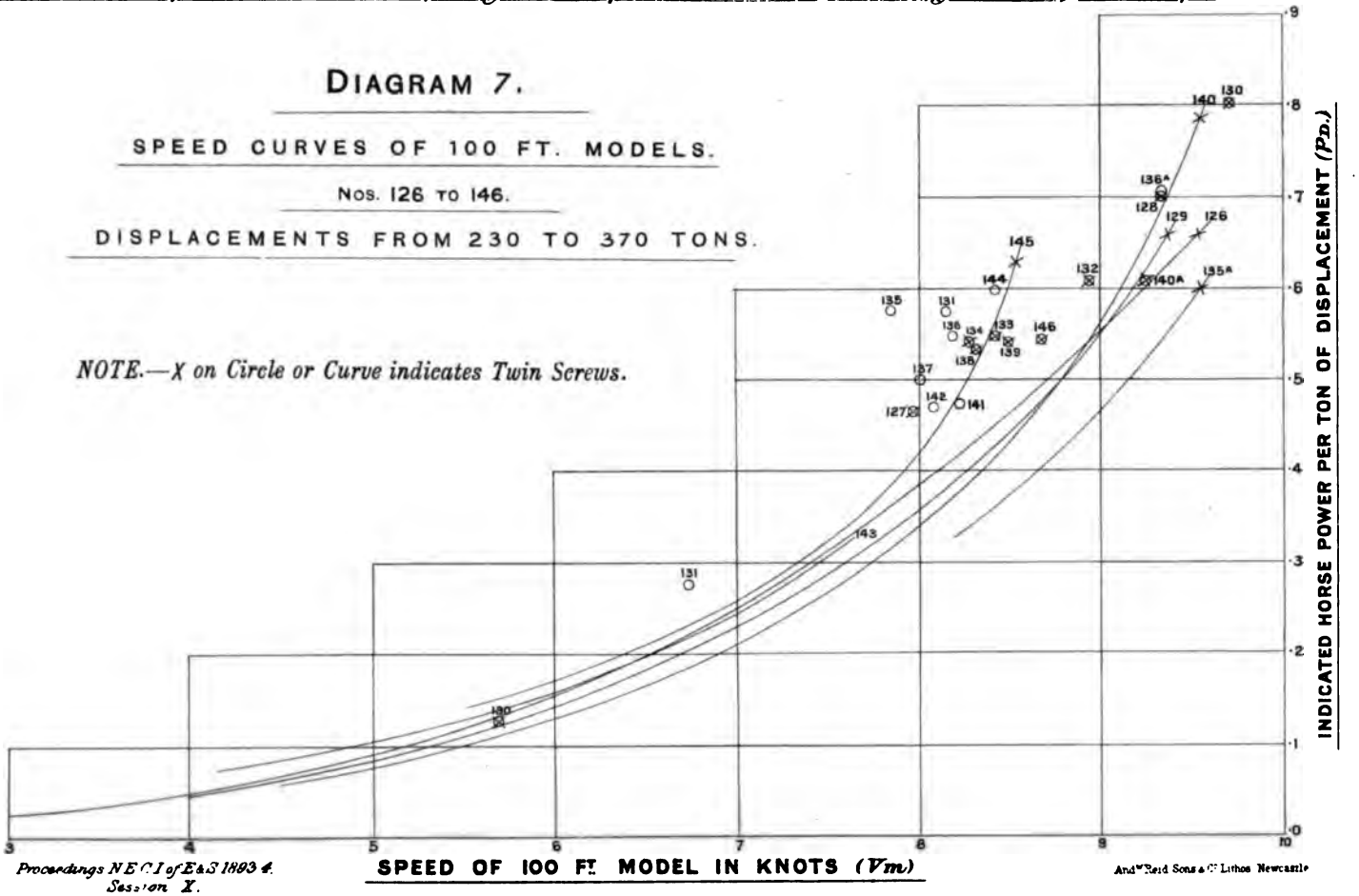

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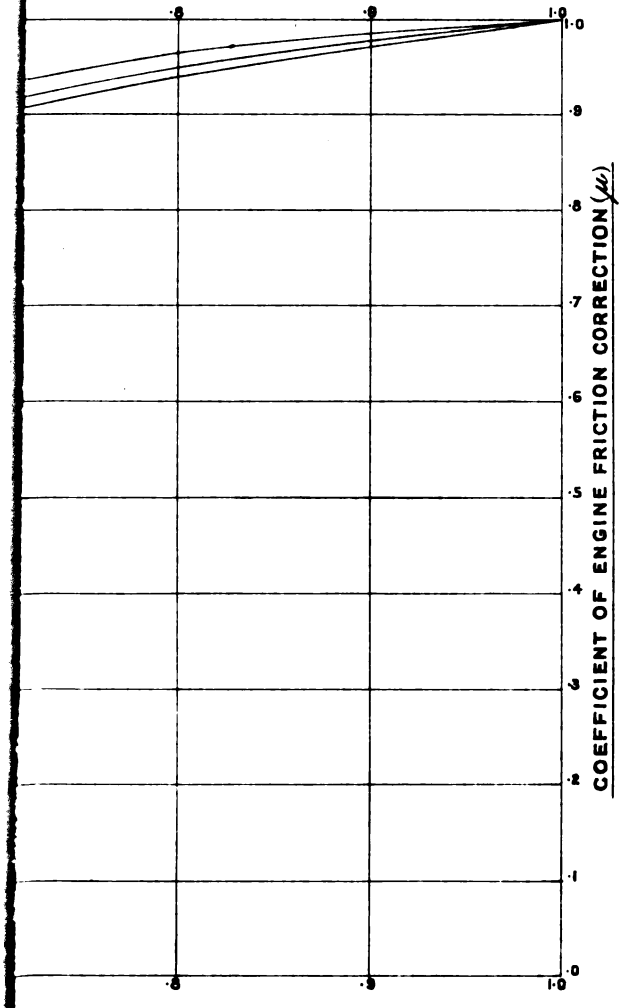

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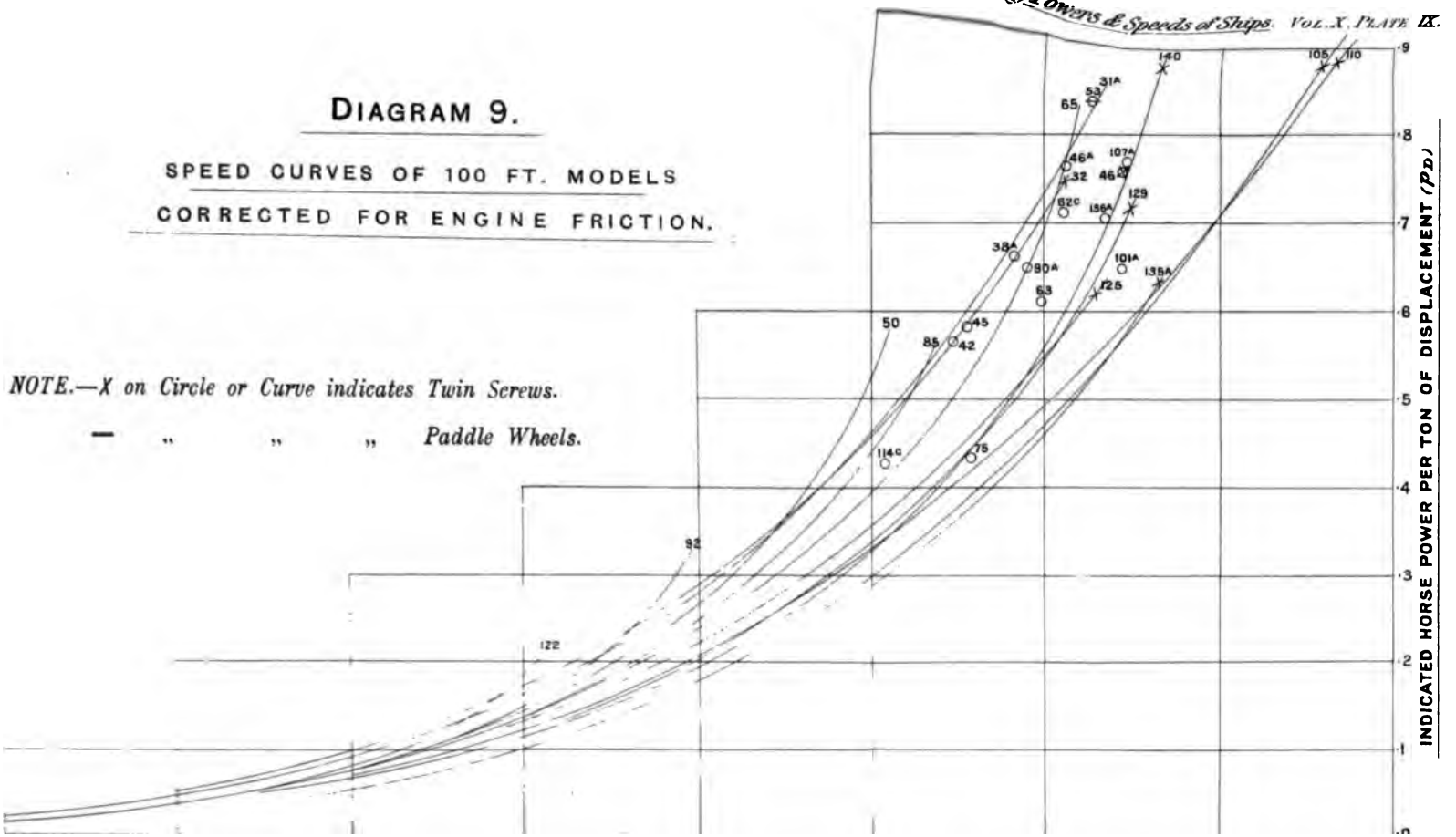
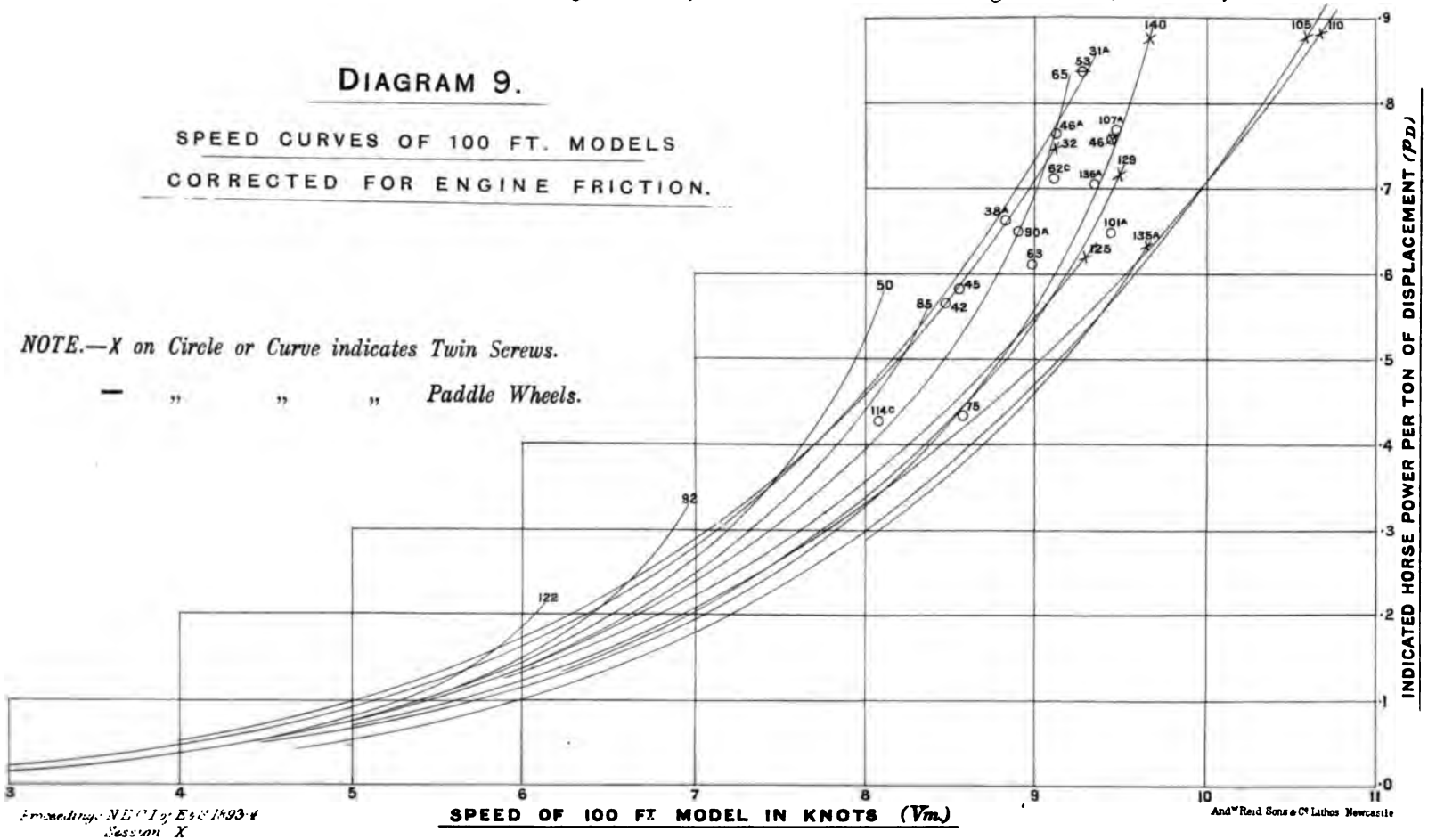


DIAGRAM 9.
SPEED CURVES OF 100 FT. MODELS
CORRECTED FOR ENGINE FRICTION.
NOTE.—X on Circle or Curve indicates Twin Screws.
— " " " Paddle Wheels.
INDICATED HORSE POWER PER TON OF DISPLACEMENT (PD)
·9
·8
·7
·6
·5
·4
·3
·2
·1
·0
140
105
110
31A
65
52
46A
107A
32
46
62C
129
136A
38A
90A
101A
135A
63
125
50
45
85
42
114C
75
92
122

To illustrate Mr. W. Hoik's Paper on "A Method of Comparing Steamship Performances & of Estimating Powers & Speeds of Ships." VOL. X. PLATE IX.



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Session X

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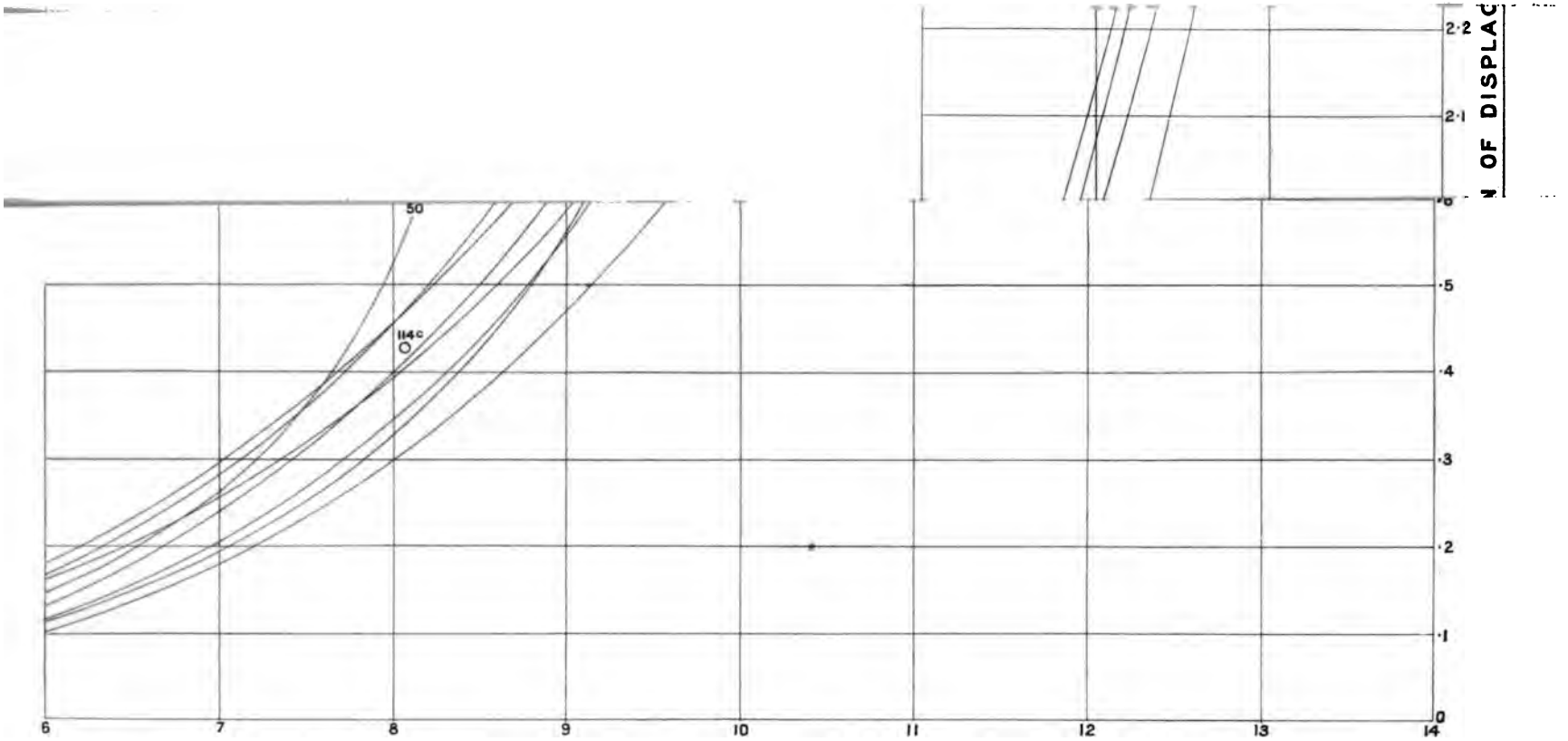
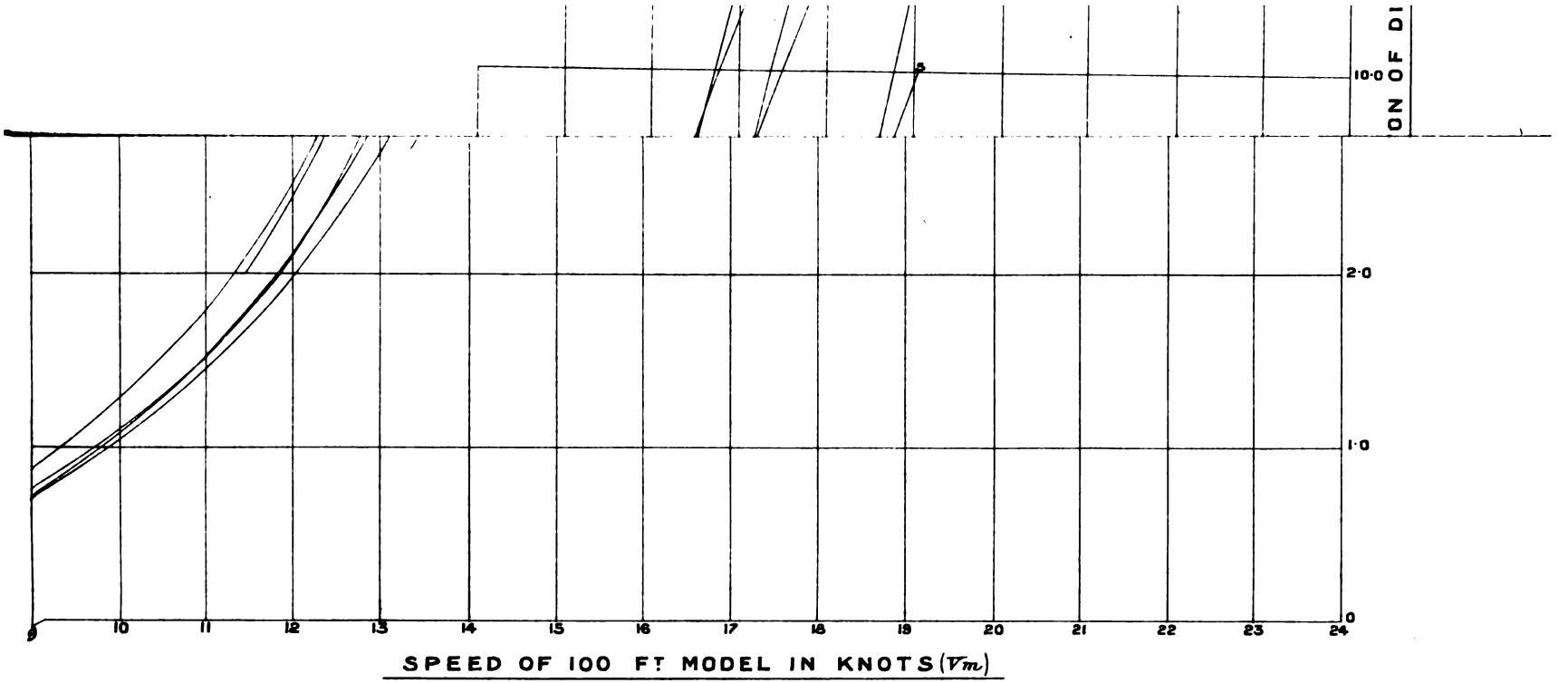


SPEED OF 100 FT MODEL IN KNOTS (V_m)



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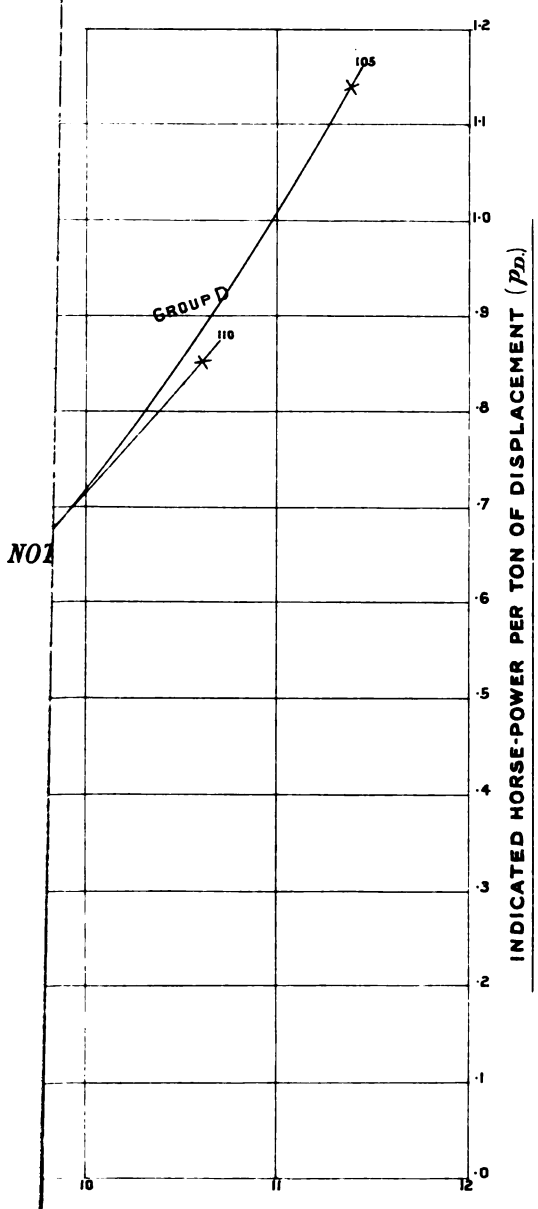

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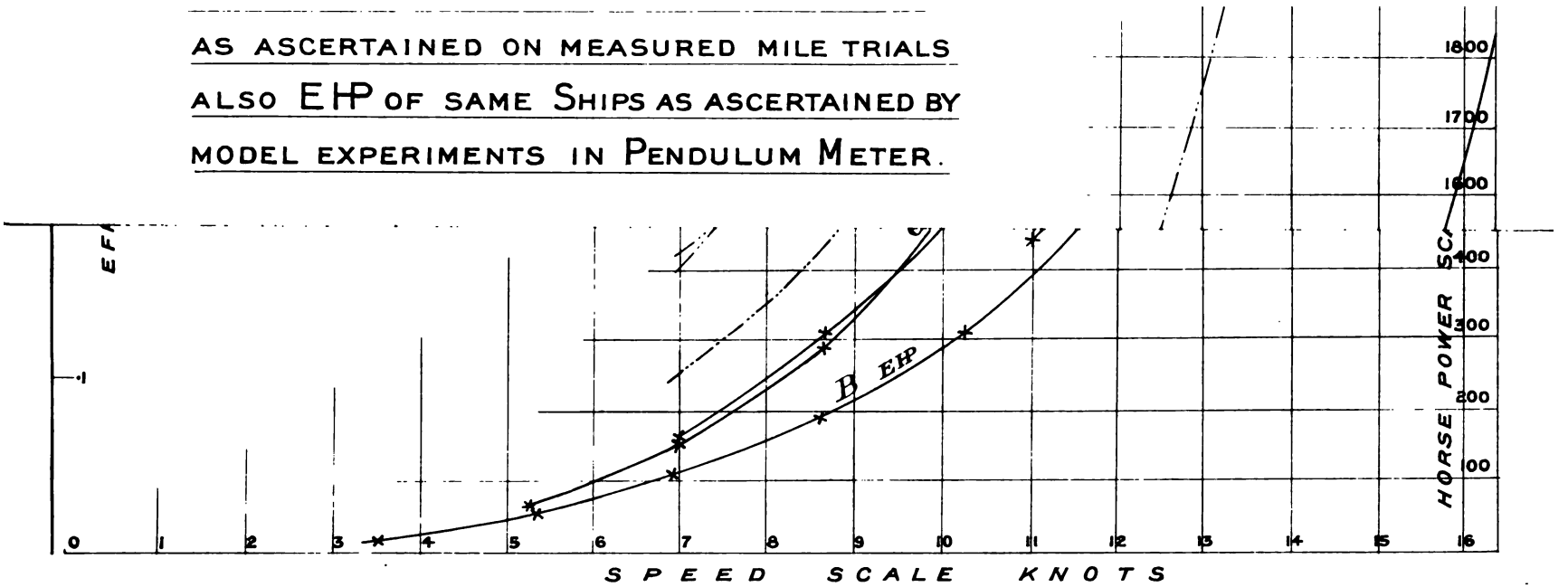
AS ASCERTAINED ON MEASURED MILE TRIALS

ALSO EHP OF SAME SHIPS AS ASCERTAINED BY

MODEL EXPERIMENTS IN PENDULUM METER.



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Session X.

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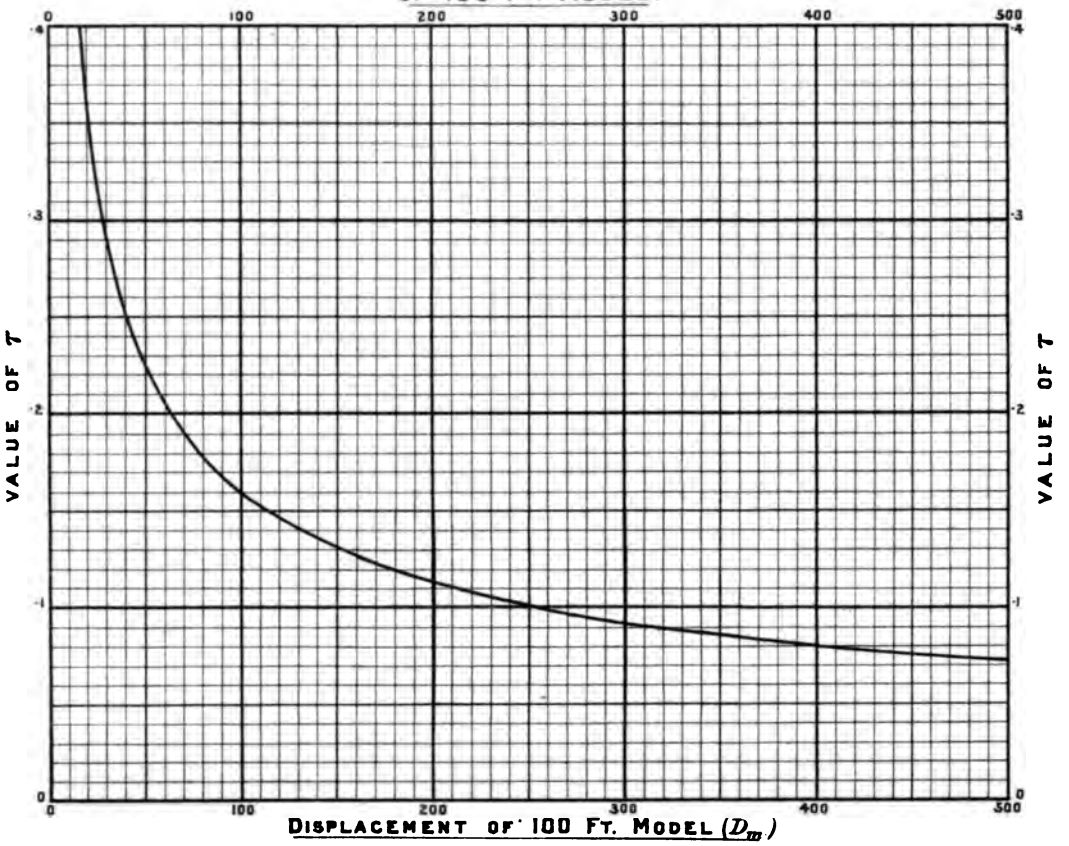
DIAGRAM 13.

CURVE OF T OR $\frac{1}{100}$ × SKINFULNESS OF DISPLACEMENT OF 100 FT. MODEL.



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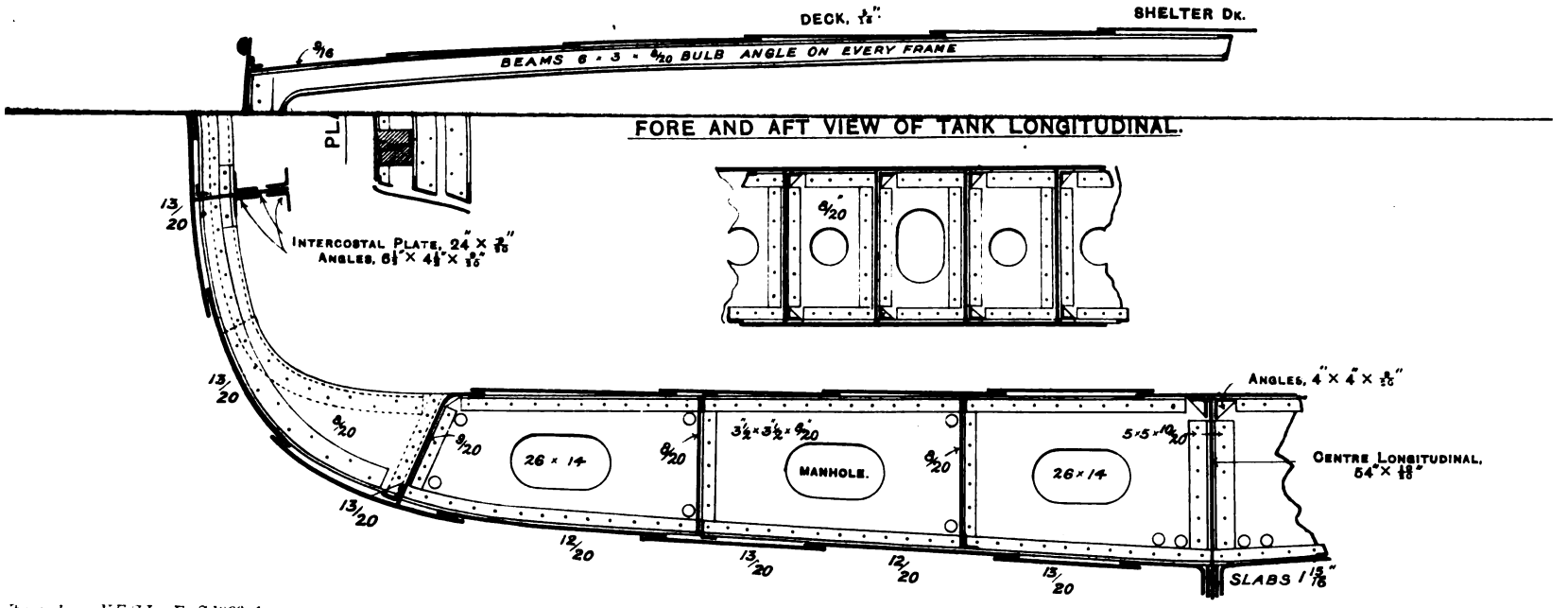
To illustrate Mr. W. Bell's Paper on "A New System of Construction for Large Vessels of Cellular Type."



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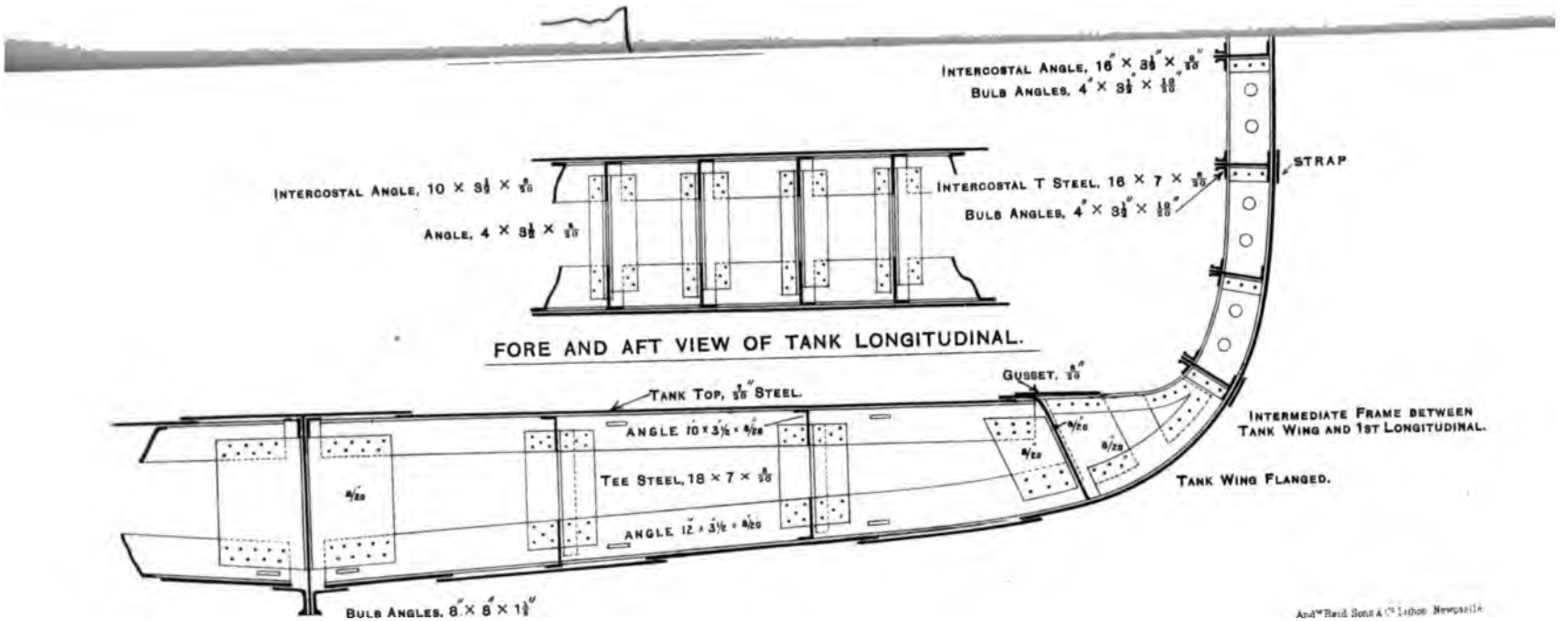
To illustrate Mr. W. Bell's Paper on "A New System of Construction for Large Vessels of Cellular Type."



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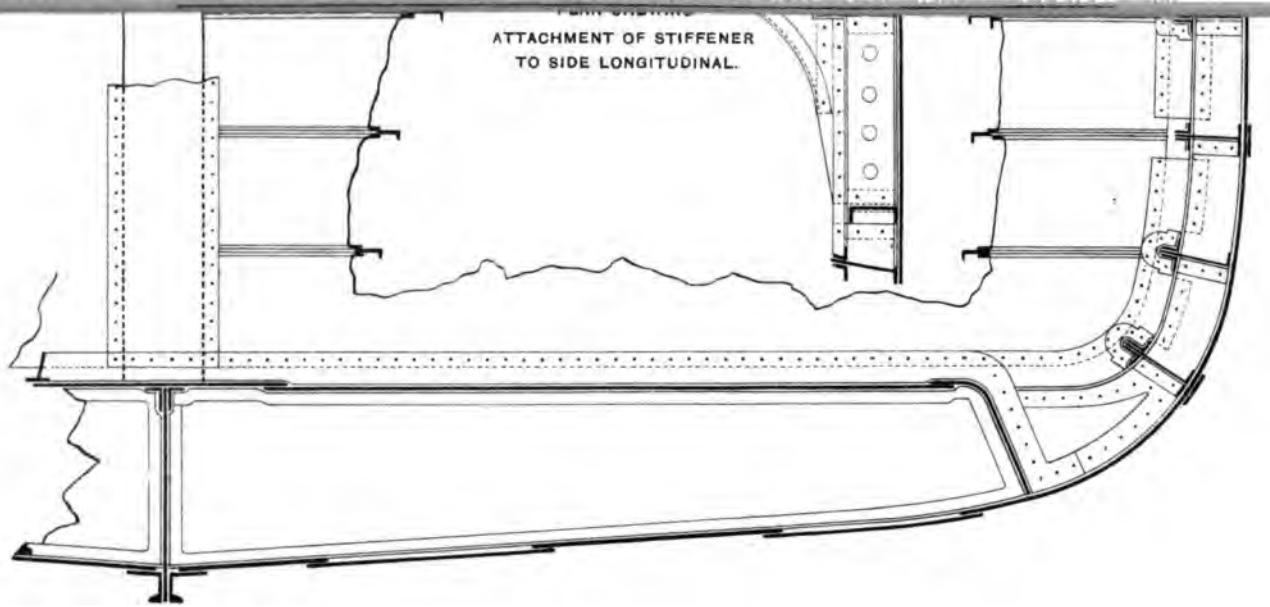
To illustrate Mr. W. Bell's Paper on "A New System of Construction for Large Vessels of Cellular Type"

ALTERNATIVE ARRANGEMENT OF FLOOR



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e Energy is absorbed by Fixed Centre.

2

PROOF BY LEVERAGE.

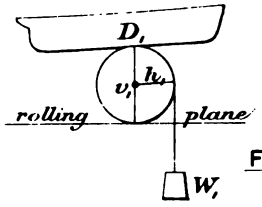

FIG. 2.

	ROLLER.
v.	Lever of D's horizontal speed = v_1.
h.	„ W's vertical „ = h_1.
cal speed.	$v_1 = 2h_1$ ∴ horizontal speed = 2 × vertical speed.

F BY ACCELERATION.

ed Pulley. Accel. = g.

l velocity of W = 1.

= 1.

f W per unit of power = $\frac{1}{1}$ = 1.

Pulley. Accel. = $\frac{g}{2}$.

l velocity of W = ·707.

ital „ „ D = ·707.

= ·707.

f W per unit of power = $\frac{707}{707}$ = 1.

D „ „ = „ = 1.

Roller. Accel. = $\frac{g}{5}$.

l velocity of W = ·4472.

ital „ „ D = ·8944.

= ·4472.

f W per unit of power = $\frac{4472}{4472}$ = 1.

D „ „ = $\frac{8944}{4472}$ = 2.

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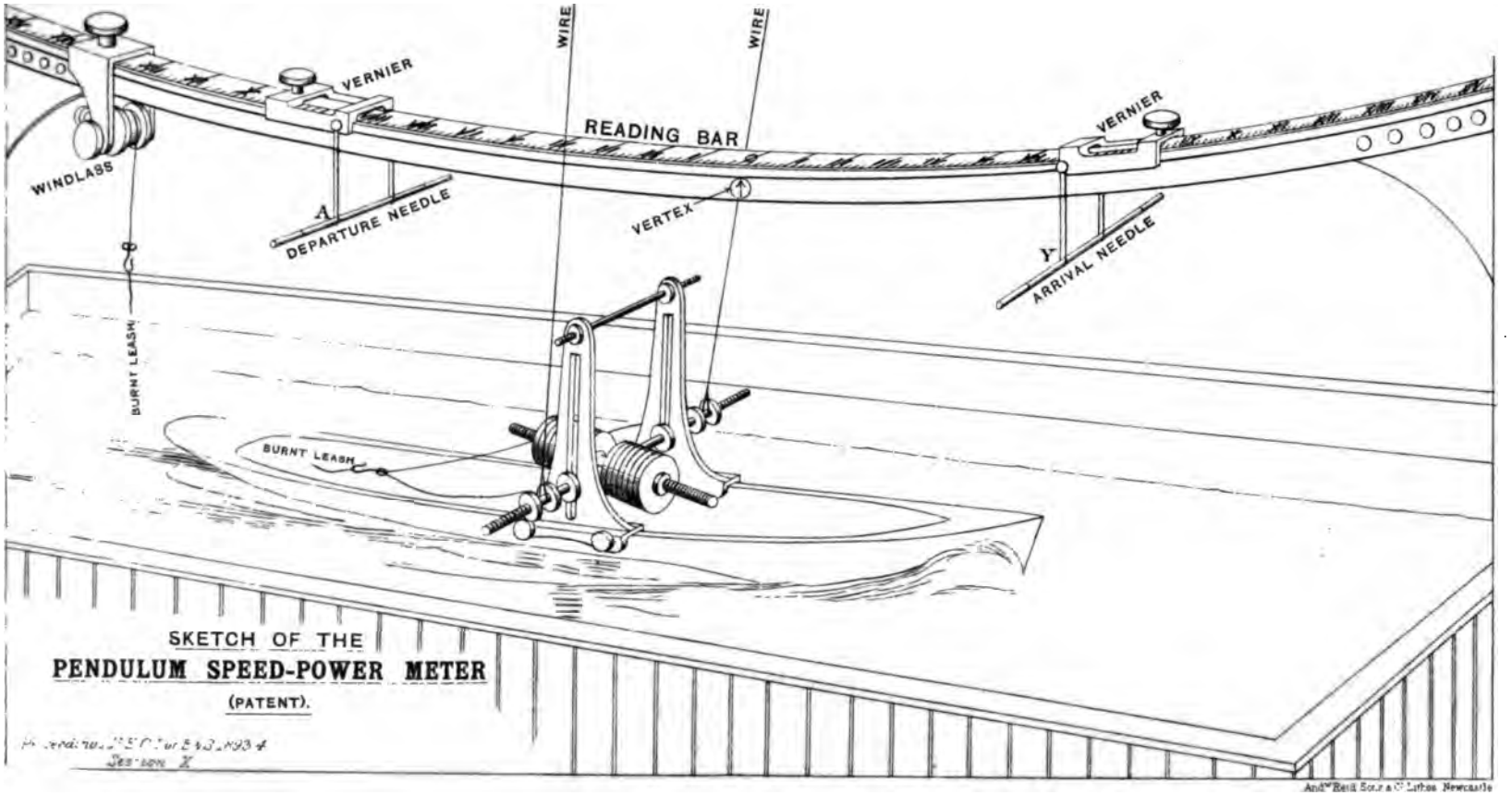

SKETCH OF THE
PENDULUM SPEED-POWER METER
(PATENT).

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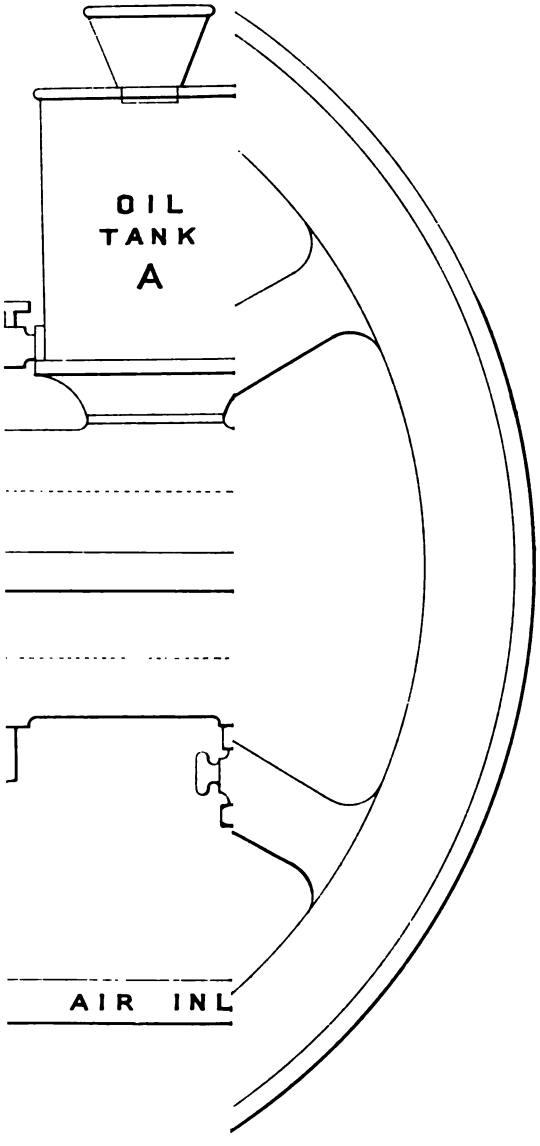
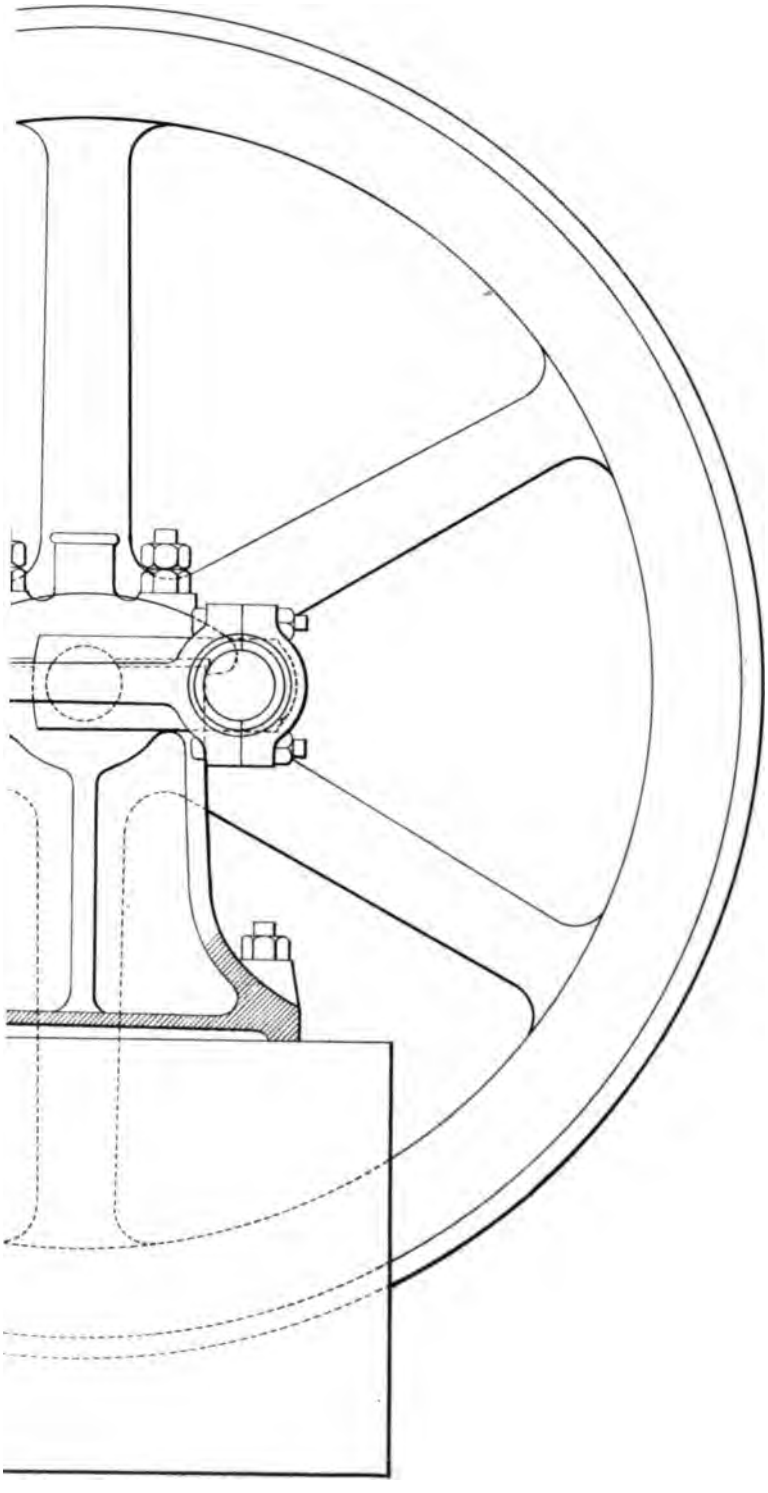

OIL
TANK
A
AIR INL



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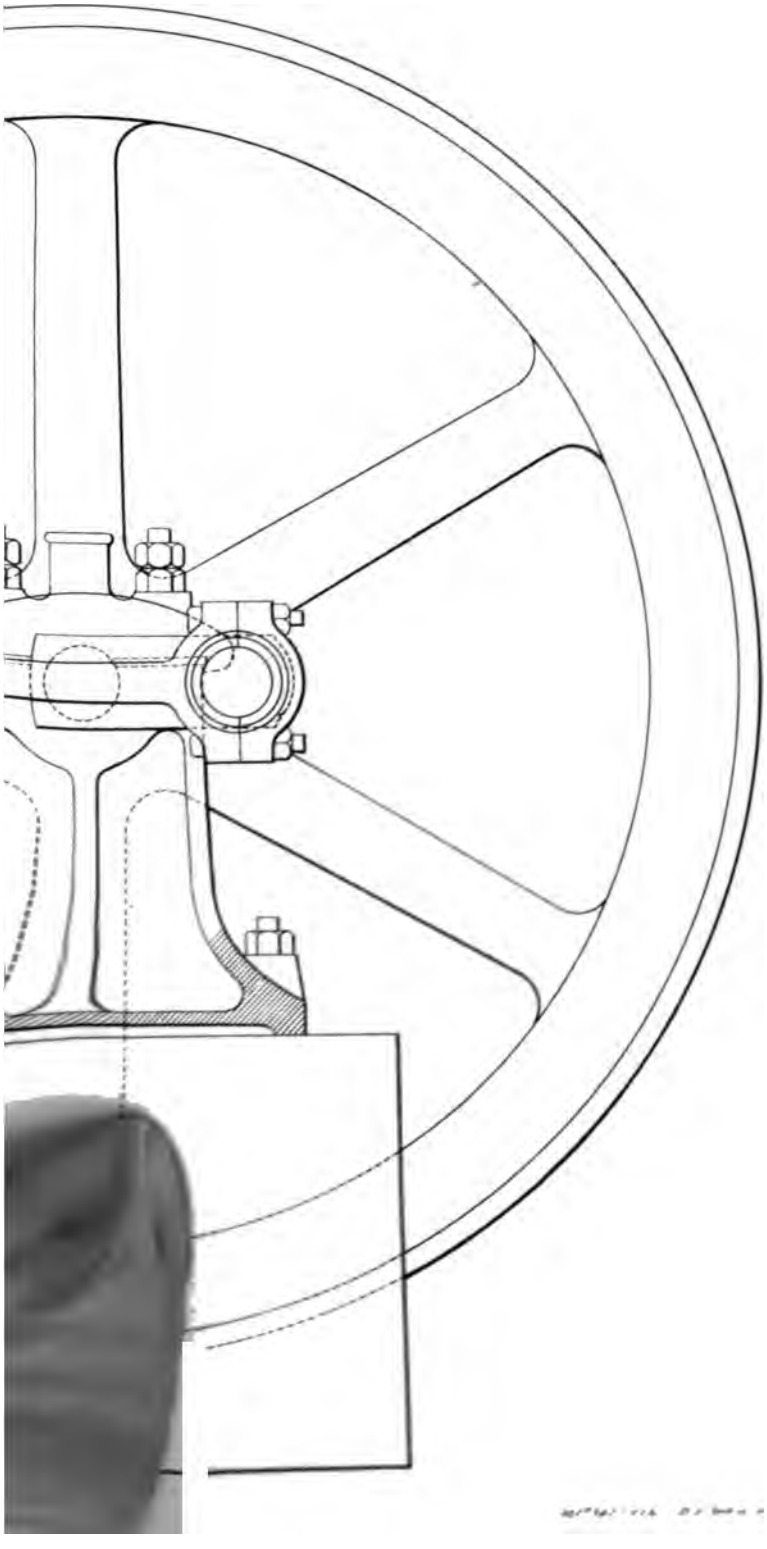

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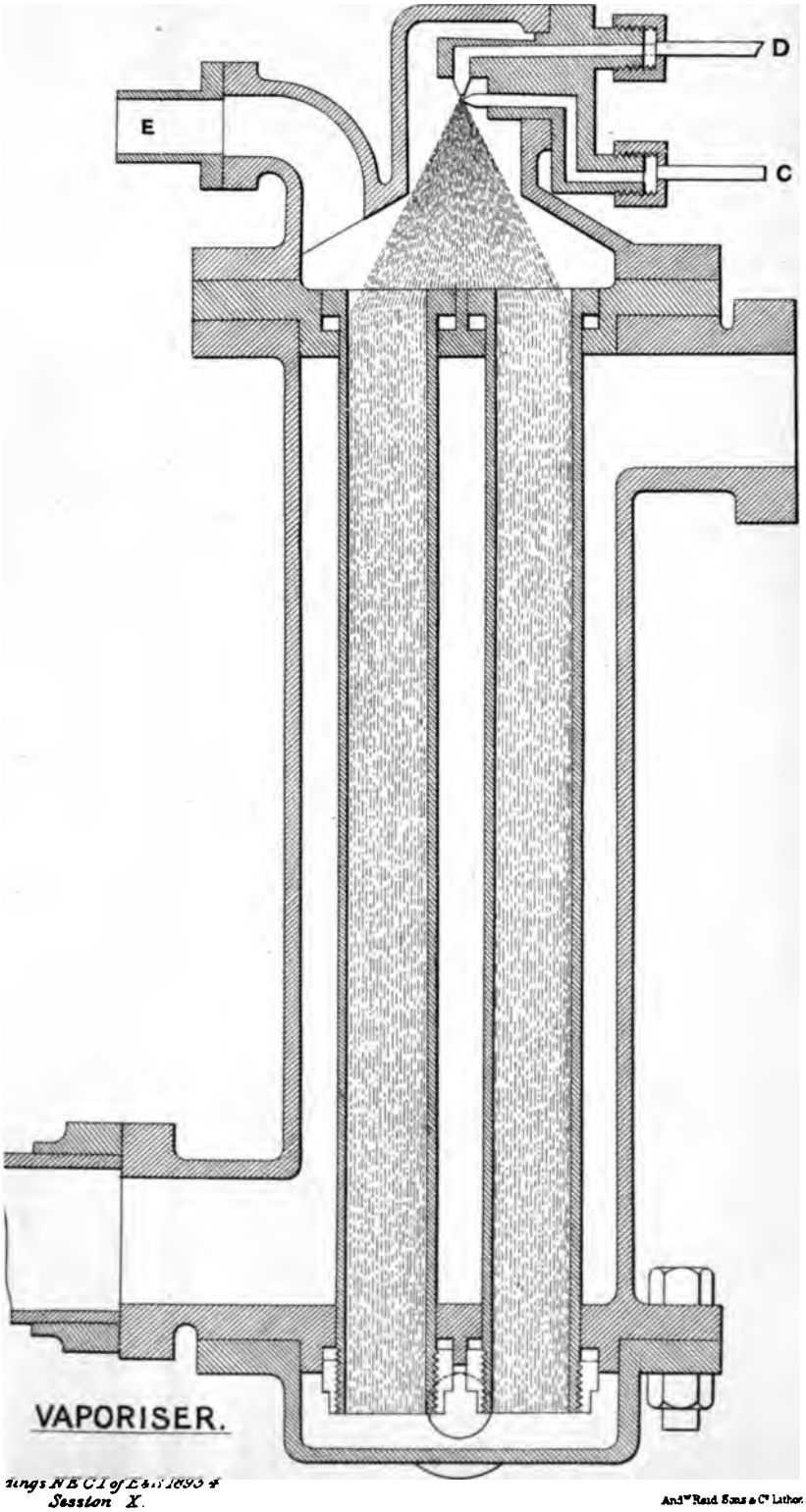

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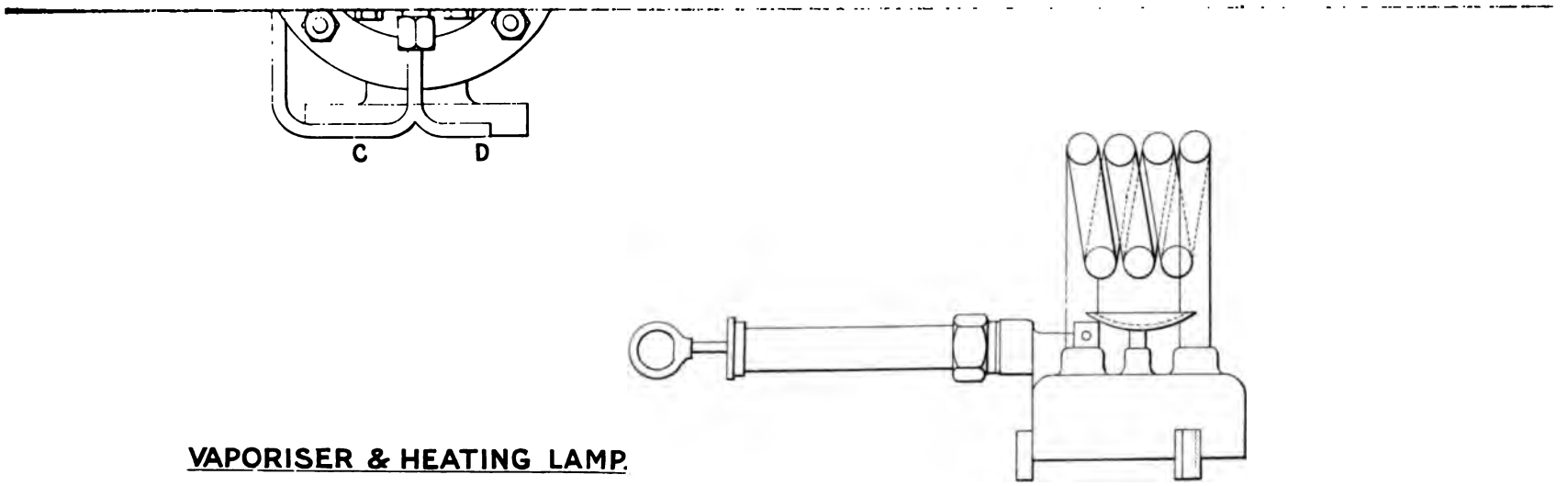

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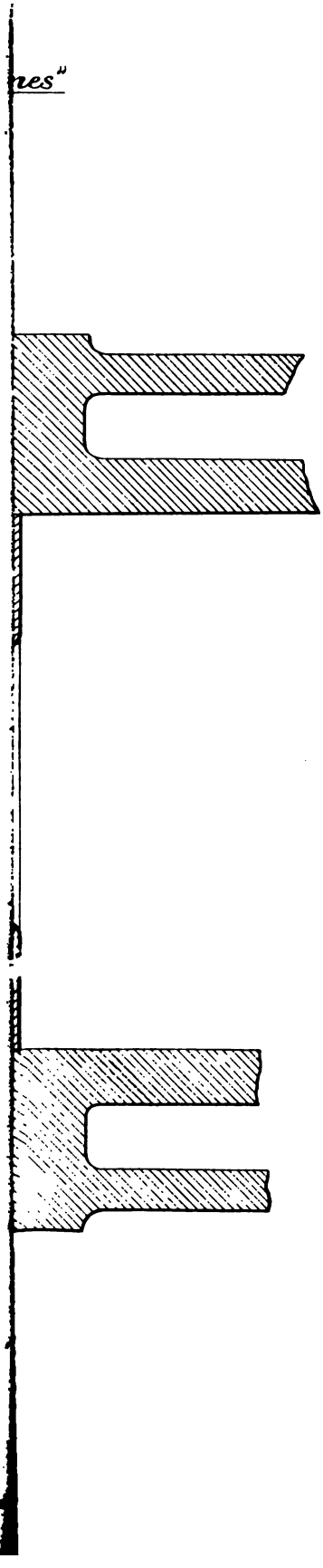

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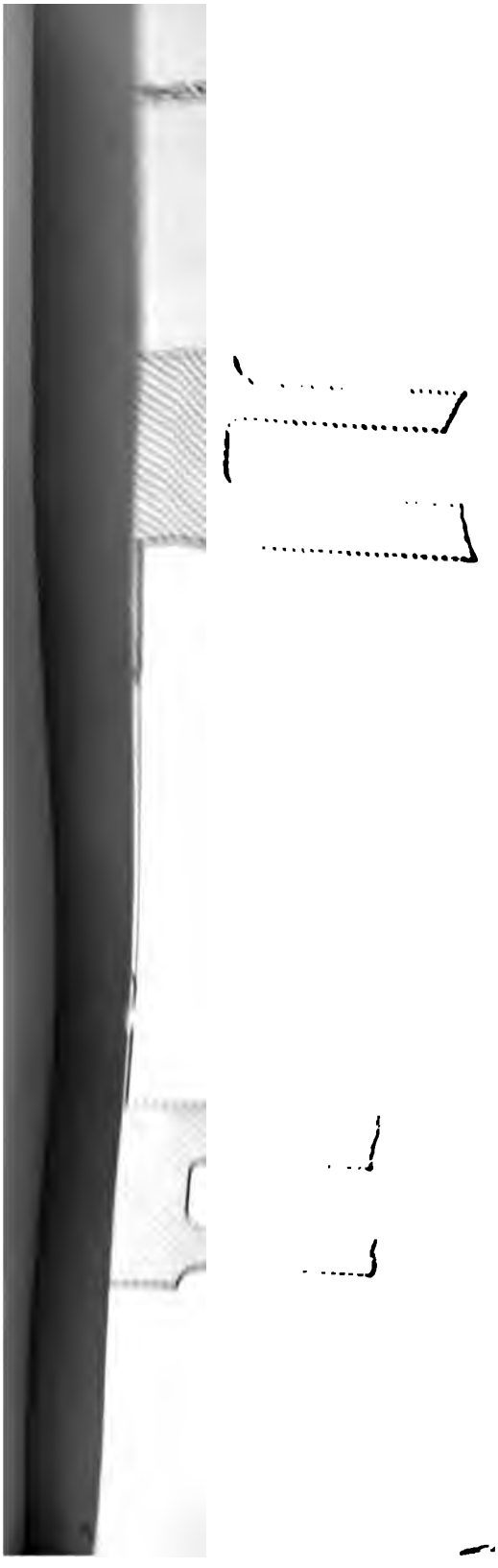

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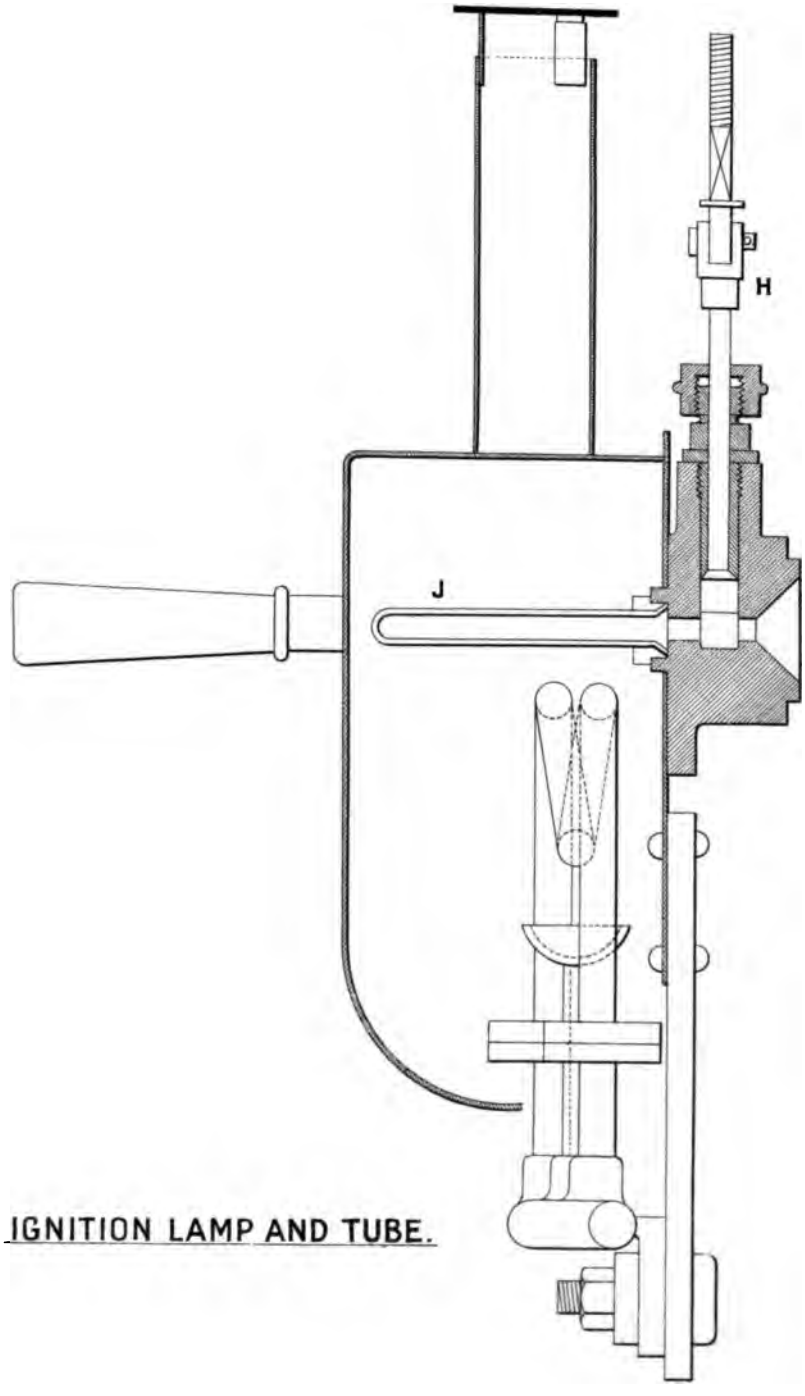

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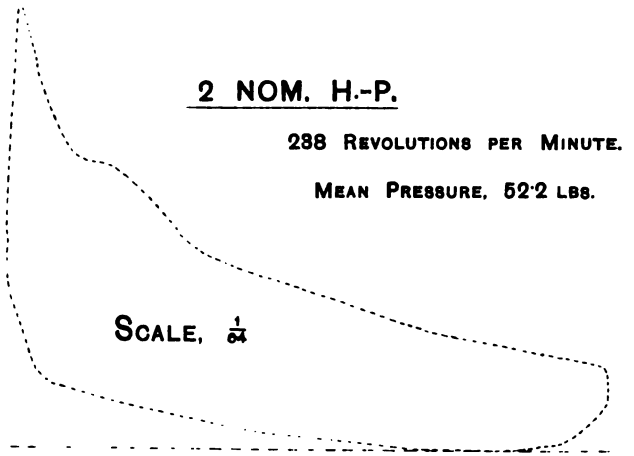

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No. 4.

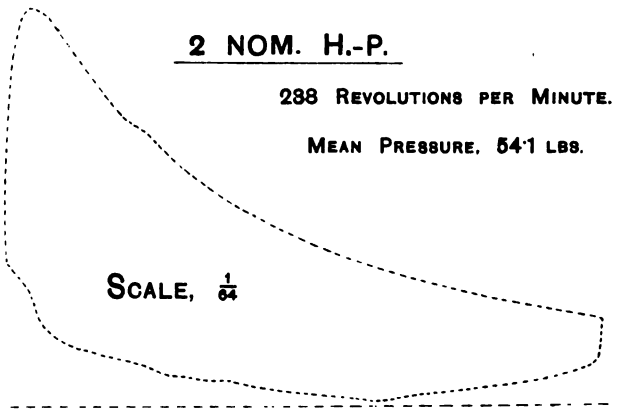

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FIG. 3.

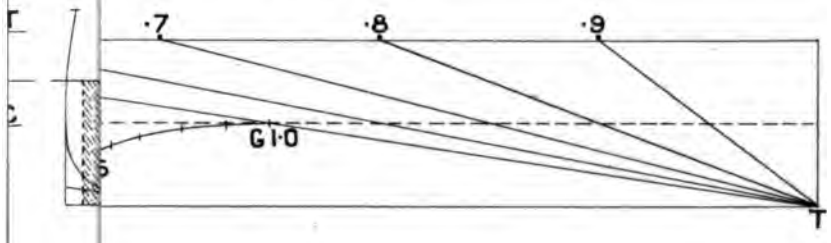


FIG. 6.

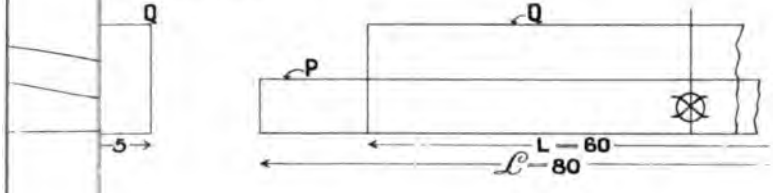
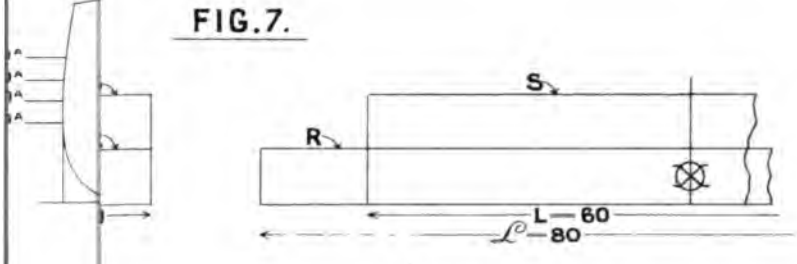
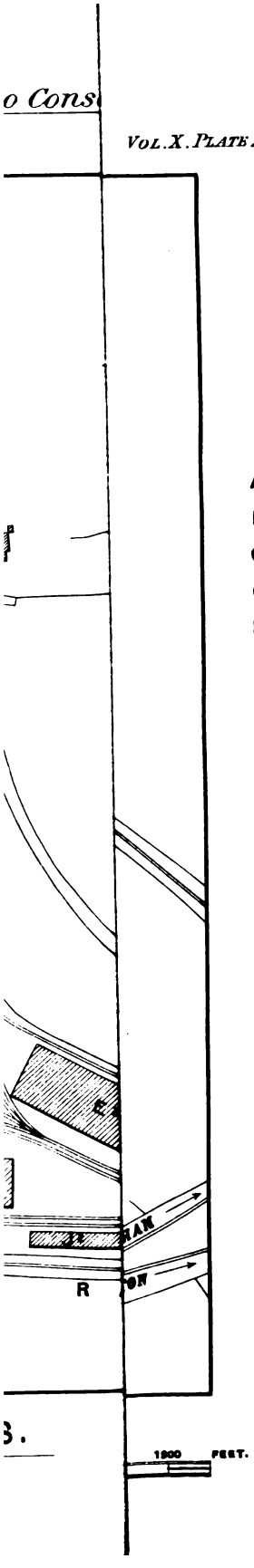


FIG. 7.





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B. BLAST FURNACES.

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C². " " (TIN MILL.)

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E². EAST " "

E³. NORTH " "

F¹. No. 2 STEEL COGGING MILL.

F². No. 4 " " "

G¹. Nos. 1 & 2 STEEL PLATE MILLS.

G². Nos. 3 & 4 " " "

H. ANGLE MILLS.

J¹. GAS PRODUCERS (WEST SHOP.)

J². " " (EAST SHOP.)

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